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CLOSED LOOP SOLID STATE CONTROL SYSTEM FOR DC MACHINES IN INDUSTRY — P. G. BHAT

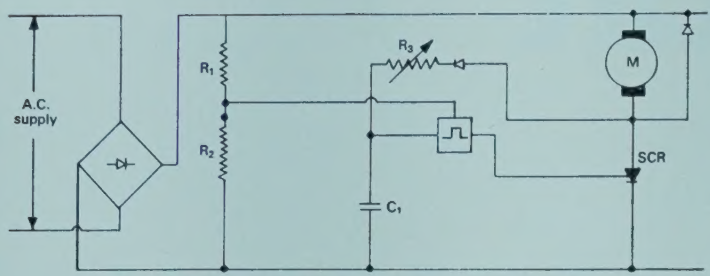


Fig. 1 Simple circuit showing speed control of constant field Shunt Motor using SCR (shunt field not shown)

The direct current machine with the solid state control is ideally suited to provide smooth and wide range of speed control desired in the modern industry.

The speed of a separately excited shunt wound motor is (inherently) reasonably constant with changes in torque, thus permitting speed control to be achieved by controlling the voltage applied to the armature.

The use of a small auxiliary (compound) winding can make the speed virtually independent of torque. Similarly a feed back information of speed into the control that supplies the armature voltage will reduce variations of speed with torque.

A simple circuit, Figure 1, showing the speed control of a constant field shunt motor, governed by the voltage, delivered by a single SCR is an example of feed back of speed in the form of back EMF. The phase angle at which the SCR would fire, depends on the time required for C1 to reach the breakover voltage of the trigger unit (say a unijunction transistor or silicon unilateral switch). This time is controlled by the magnitude of resistor R3 and the voltage across the SCR. The voltage in turn is equal to the voltage across the diode bridge rectifier (supplying fullwave DC voltage), minus the back EMF across the armature.

Any increase in the load current which tries to reduce speed would mean reduced back EMF. This in turn enables Capacitor C1 to charge faster (or earlier) during each half cycle so that the voltage across SCR falls, consequently giving the set speed.

Such a control would be limited to smaller drives and will have limited range of regulation. The requirement of industrial drives on the other hand calls for more versatile closed loop control. Besides speed regulation to higher accuracy, it calls for current limitation to contain the current to the specified limit of the power semiconductor components.

Further, the transducers sensing speed, current voltage or any other parameter must be coupled to the control circuits and the gate firing circuits which must be potential free (galvanically separated) with respect to the mains, feeding the power semiconductor.

In order to achieve such regulation, a ' multi-loop control system ' is used, wherein there are more than one closed loop control systems.

The use of multi-loop controllers becomes essential when :

(1) Besides the main controlled variable other parameters are to be monitored additionally.

(2) Dynamic qualities of the control system are to be improved (e.g. when there are two or more than two distinct time constants involved in the loop).

A two loop control is shown in Figure 2. The figure shows the most common speed controller with subordinated current controller (for armature control), amongst the multi-loop controls for drives.

The feature of such a system is that the external loop (speed control loop) contains another member within, which in itself is a closed loop (current control loop).

The speed control has a subordinated armature current control. The main controlled variable is the speed; the armature current is an auxiliary or the subordinated controlled variable. Besides limiting the armature current, it runs the motors to its best possible performance.

When a motor is required to accelerate or change its speed to a desired value with speed controller only, it should be done in such a manner that at any time

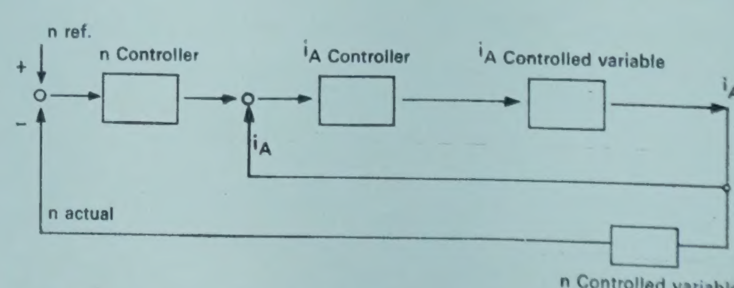


Fig. 2 Two loop controller

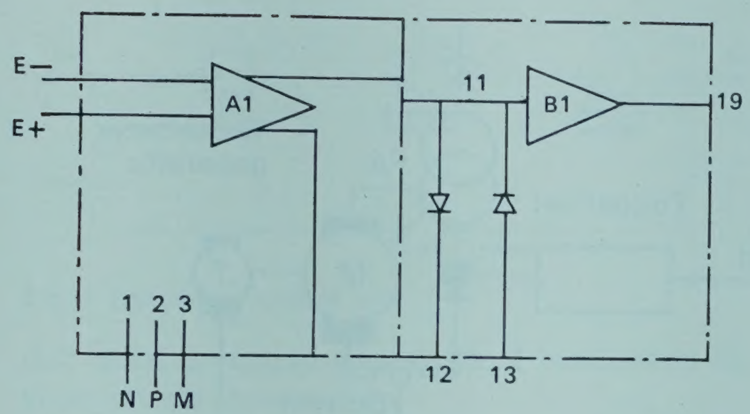


Fig. 3 a

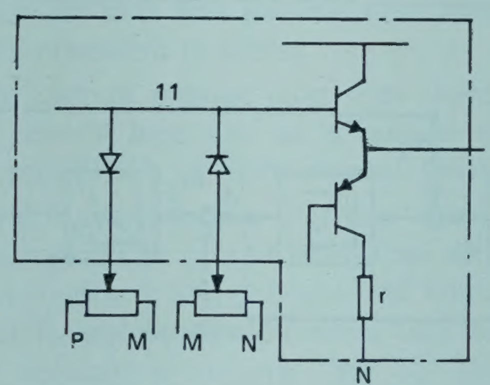


Fig. 3 b

Fig. 3a and 3b Limiting of current

the current does not exceed the permissible value. Without the current controller, the speed controller is to be optimised slow enough to ensure that the desired change in speed is achieved without the controller reaching its limit. Since the optimised loop has only one setting (which is generally done on load), the acceleration of smaller loads or no load will be slower than expected (because of the response time which has been fixed as per full load conditions).

On the other hand if the speed controller output acts as a reference value for the current controller, its comparison with the actual value of the current ensures that even at smaller loads the maximum current is available to accelerate the motor. Since the response time of the current controller is much less as compared to the response time of the speed controller, this arrangement ensures quick acceleration at smaller loads and prevents the controller to go to its limit thereby providing a stable drive.

The following example would show how, the acceleration time of a motor with load improves by using this system.

$$t_{Ho} = \frac{T_H}{K\varphi - w} \quad .. \text{(i)}$$

Example

1) $T_H = 1$ (sec.)

$\varphi = 1$ (full flux)

$K = 2$,

At no load

a) $t_{Ho} = \frac{1}{2-1} = 1$ sec

b) $t_{HI} = \frac{1}{2-0} = 0.5$ secs.

Example (2) At half the rated load

a) $t_{Ho} = \frac{1}{2-1} = 1$ sec.

b) $t_{HI} = \frac{1}{2-0.5} = 0.67$ sec.

When

$$K = \frac{\text{Imax}}{\text{I rated}}$$

$$w = \frac{W}{Mn} = \frac{\text{load torque}}{\text{rated torque}}$$

$$\varphi = \frac{\phi}{\phi_N} = \frac{\text{actual flux}}{\text{rated flux}}$$

T_H = Mechanical time constant of the motor.

t_{Ho} = Acceleration time with only speed controller.

t_{HI} = Acc. time with speed & subordinated current controller.

Similarly when the speed reference changes suddenly, the motor adjusts to its new value faster, at the same time containing the current to the maximum permissible value.

Limiting of the current is achieved in a controller by clipping the output voltage of speed controller within specified limits. The block diagram, Figure 3a, shows a two stage DC voltage differential amplifier A1, two limiter inputs (12, 13) and a DC amplifier B1. The input amplifier can be a normal voltage amplifier with discrete components or an integrated circuit.

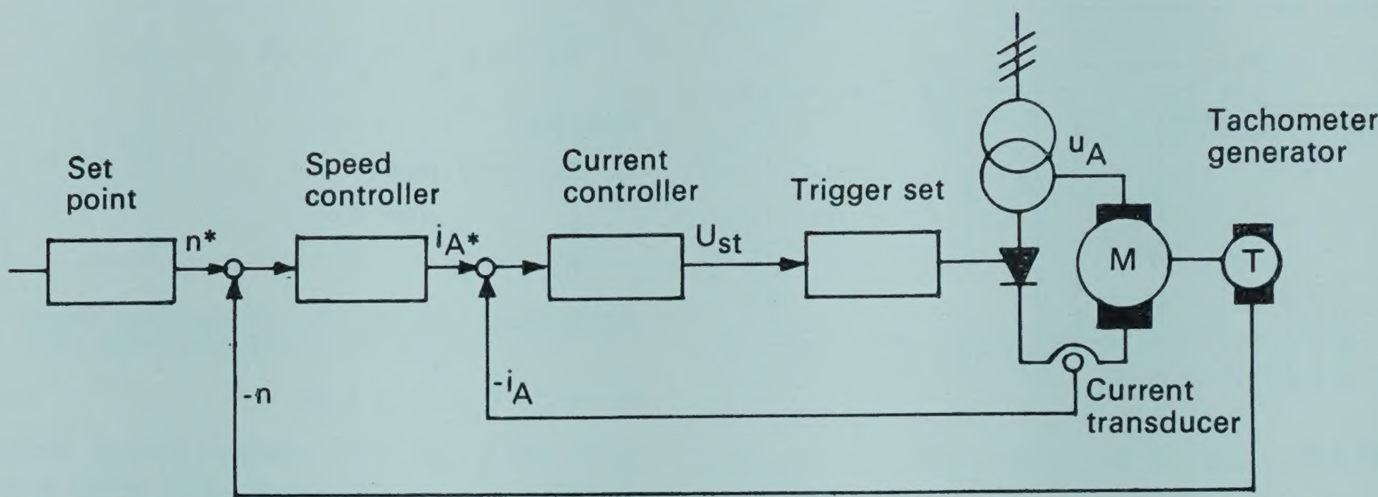


Fig. 4a Schematic diagram

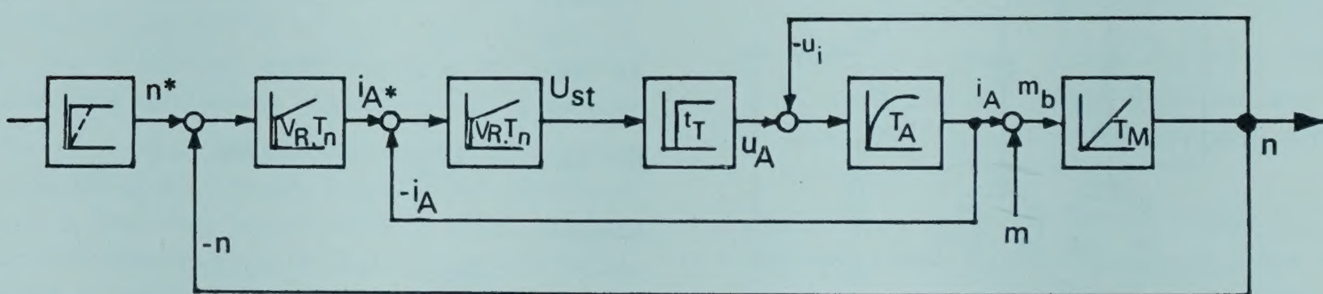


Fig. 4b Closed loop block diagram

n	Actual speed (controlled variable)	u_i	Armature counter e.m.f.
n^*	Speed set point (reference variable)	m_b	Accelerating torque
i_A	Actual armature current (assumed to be proportional to torque)	m	Load torque
A^*	Armature current set point	$V_R. T_n$	Controller PI parameters
U_{st}	Input signal to trigger set (current controller output signal)	t_T	Converter dead time
u_A	Converter voltage at armature	T_A	Armature circuit time constant
		T_M	Mechanical time constant

Fig. 4 Example of Siemens transistorised control system

The Figure 3b shows the limitor circuit. The positive going voltage at 11 will be clipped to a voltage set by the potentiometer M-P. The diode in 11-12 will start conducting beyond this voltage plus 0.67 volts. Similarly the negative voltage will be limited by the circuit 11-13. The threshold voltage is almost compensated by the threshold voltage of the base-emitter junction of the transistors of the push-pull amplifier. By adjusting the limiting point the maximum operating current of the drive can be set.

The TRANSIDYN Control system developed by Siemens has been in use in all branches of industries since many years. The schematic diagram of representative feedback, Figure 4a, along with the block diagram, Figure 4b, shows once again an example of the speed control with subordinated current control over the SCR fed DC drive. The block diagram shows in details the controllers and the controlled variables with time constants.

It would be noted in the foregoing diagrams that the PI (Proportional-Integral) Controllers are used as speed and current controllers. The P band offers a

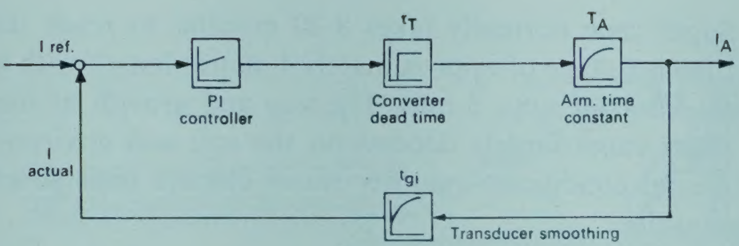


Fig. 5 The current control loop

fast initial advantage whereas the I band caters for good control characteristic.

Optimising of the controllers means, to adjust the feed back elements such that the system adjusts itself to a new stable condition in best possible time when the original stable condition is altered.

The subordinated current control loop with superordinated speed control loop has an advantage of relatively easy optimisation of both control loops. In each of the control loops there is only one ' large ' time constant (compared to sum of small time constants); the current control loop contains the armature time constant T_A and the speed control loop the mechanical time constant or integral time T_i. The optimisation is carried out first in the inner loop (current loop) then with the equivalent time constant on the speed controller. Figure 5 shows the current control loop. This contains the controller output gate control set and converter, the armature circuit with DC motor and transducer. At the input, comparison is made between reference input value (output of speed controller) and the controlled variable from armature current transducer.

The optimization would take into account the converter dead time t_T, the electrical or armature circuit time constant T_A and the transducer filter time constant t_{gi}. Based on the maximum permissible current, armature resistance and the maximum motor voltage controlled process amplification is computed. With the help of this and the time constant mentioned above the controller circuitry is compiled to give the requisite current optimization.

The optimization of the speed control loop Figure 6 involves the speed controller (PI), equivalent time constant of the optimised current control loop t_{ei}, integrating time T_M and the voltage smoothing time of tachogenerator t_{gn}. With the help of above values and controlled process amplification the controller perameters for best optimization can be calculated.

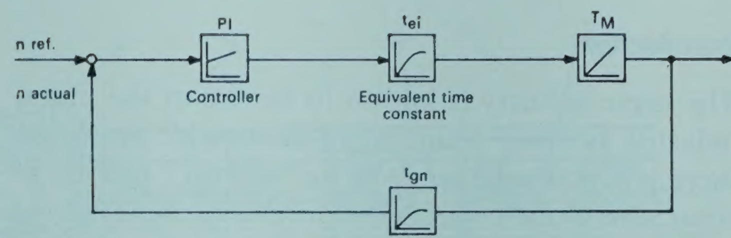


Fig. 6 The optimization of the speed control loop

The system concept and design of equipment layout enables one to adjust the parameters easily in the TRANSIDYN® Controllers (P&I). With the help of this the matching of the components is done comfortably for any given controlled variable.

Figure 7 shows the transient response of the controlled variable in a control loop when the nominal value is suddenly altered at the controller input.

For optimizing the TRANSIDYN® Controllers, simple procedures are set with the help of which one can set the controllers to required optimum conditions for any type of controller variable. For this purpose fast response recorders are used, which show the response of the drive when a step input is applied.

The TRANSIDYN® closed loop controller which is a system in itself is versatile enough to accommodate or match with various types of process control variables, such as tension, temperature, pressure etc. measured with suitable transducers.

SIMADYN C, is the latest development of the above system using high quality IC operational amplifiers to ensure optimum matching of the component parts. It gives a reliable modern IC modular control system.

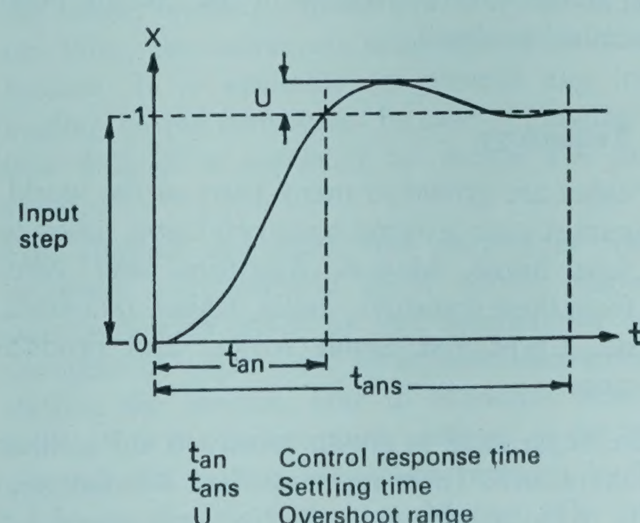


Fig. 7 Transient response of controlled variable

DRIVES FOR SUGAR MILLING PLANTS

—S. N. GHOSH

Introduction

The sugar industry is known to be one of the oldest industry in many countries of the world. However, there is a gradual change in the recovery process of sugar, from cane or beet. The primitive hand crushing machine is being replaced by the modern electric driven milling plants.

During the last two decades there has been a rapid growth of the sugar industry in our country. The production of sugar has gone up considerably during this period due to many factors—the utilisation of better soil fertilizer for the growth of sugar cane, good storage facilities for the ripe sugar cane, quick handling system for transporting the sugar cane from the field to the factories and last but not least the introduction of modern methods of recovery of sugar from cane by the use of Power Driven Milling Plants and Centrifuge Baskets.

The production capacity of sugar was estimated to be approximately 3.86 million tonnes in the year 1974-75, from 38 million tonnes of sugar cane. The government has sanctioned the installation of new units to increase the production capacity by 1.3 million tonnes. Even though, this may not be achieved due to the paucity of funds, at least one million tonnes increase is anticipated.

The production of sugar depends largely on the growth of sugar cane, the processing of cane by milling plants and the formation of sugar crystals from juices by centrifuging. Hence, it would be desirable to know the basic process of sugar technology, before various aspects of the milling plant are described in detail.

Sugar Technology

Sugar canes are grown in many parts of the world. The foremost cane growing country is Cuba, followed by U.S.A, Brazil, Mexico, Argentina and Peru. Apart from these countries, India, China, Indonesia, Malaysia, Egypt and South Africa also produce sugar canes.

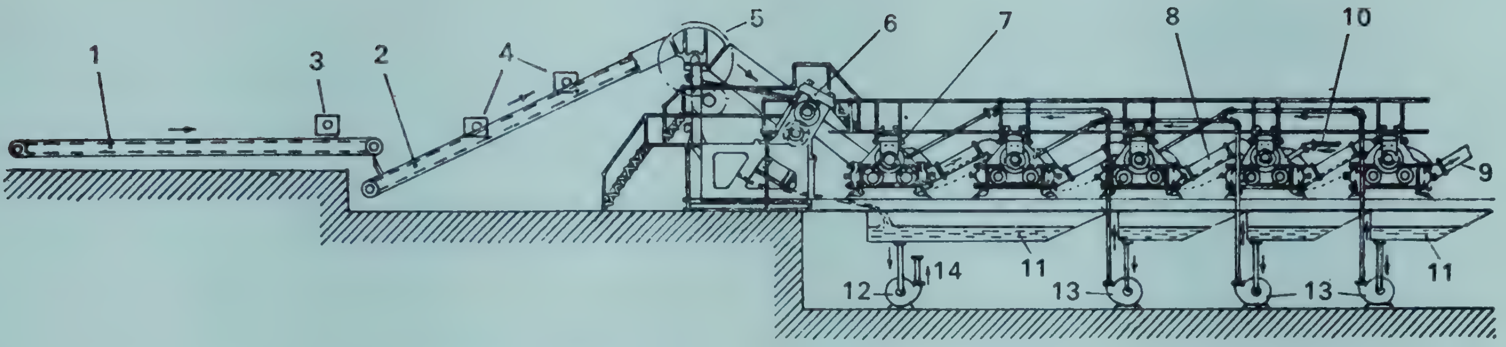
In India, sugar cane is grown mostly in U.P., Bihar and Maharashtra. There are more than 200 factories in India, with an annual production capacity of 3.5 million tonnes.

Sugar cane normally takes 8-20 months to reach its ripening stage of approximately 4 metres length with a thickness of upto 5 mm. The size and growth of the sugar canes largely depend on the soil and environmental conditions—namely warm climate with good sunshine.

After harvesting the sugar cane from the fields, it is transported to the mills by quick transport systems for immediate processing in order to avoid sugar losses during storage. The sugar cane is then unloaded to a feeder conveyor system and transported to an inclined main conveyor and ultimately to the milling plants. Levelling knives are mounted over the feeder conveyor to level the canes. These levelling knives are rotating at constant speed. The levelled canes are passed through a level gauge and then past two or three cutting knives, fitted on the inclined main conveyor. The canes are cut into desired sizes and properly levelled so that a uniform layer cut cane is supplied to the milling plant. In case the cane layer is not uniform and properly levelled, there will be irregular loading on the milling plant, resulting in short overloads on the cutters. The irregular loading and piling of materials at the first mill can be prevented by reducing the conveyor speed from the control desk, installed at the highest point of the conveyor system. The main conveyor speed is controlled automatically as a function of the load on the knives and the thickness of the cane layer. As such the conveyor requires a variable speed. The variable speed could be achieved by one of the conventional variable speed drives, namely either AC slipring induction motor, shunt wound commutator motor, or DC shunt wound motor. Sometimes a crusher is mounted ahead of the first set of rolls to reduce the size of cane-chips.

The properly sized cane chips are then fed to the milling plants. The milling plant normally consists of five or six sets of grinding rolls which are arranged one behind the other. The grinding rolls press out the canes at a high pressure of 400-500 tonnes. The rolls are driven through a reduction gear system and operate at a very slow speed between 3 to 6 rpm.

The sugar juice is collected under the individual mill, which is sprayed on to the cane blanket entering the next mill, in order to attain the maximum recovery



1 Cane feeder conveyor	4 Cutting knives	7 Mills	10 Maceration water	13 Maceration pump
2 Main conveyor	5 Chute	8 Intermediate conveyor	11 Juice tank	14 Juice line to clarification centre
3 Levelling knives	6 Crusher	9 Bagasse conveyor	12 Juice pump	

Fig. 1 Schematic arrangement of a Sugar Cane Milling Plant

of the extracted juice. Water is applied to the cane blanket before it enters the last mill so that the last trace of sucrose content is recovered from the layer.

The recovery of sucrose, i.e. the percentage of sugar yield, is very much influenced by the number of grinding rolls used for milling. The pressed out milled cane, normally known as bagasse, is removed from the conveyors.

Bagasse is often used for fixing the boilers and for the manufacture of paper and fibre boards.

A milling plant can be considered efficient and economical when it is able to do the following functions :

(1) Maximum extraction of the residual sucrose from the bagasse,

(2) Measuring humidity content of the bagasse after it has left the last mill,

(3) Increased capacity in tonnes per hour.

The juices are collected in the juice tank under the mills. Juices are then further processed into the following stages :

Clarification, Evaporation and Boiling.

The sugar juices thereafter are transported into a battery of centrifuging machines. Sugar crystallisation takes place after centrifuging. Sugar is then collected and stored.

Milling Plant Machinery

In a sugar milling plant, various types of machineries are employed for different jobs, such as feeder and main conveyors, cutter, leveller, crusher, pumps and the Mills. The main equipment is classified in five important sections, which are as follows :

(1) Conveyors (2) Cutter and leveller (3) Crusher (4) Mills (5) Pumps

Conveyors

The function of the conveyors is to transport the raw materials, i.e. the sugar cane from the loading station to the Mills. First the material is loaded at the feeder conveyor and then transferred to the inclined main conveyor before it reaches the milling plant via the crusher. The milled canes, i.e. bagasse are also removed through the bagasse conveyor.

For the crushing capacity of a plant of 1,500 tonnes to 2,000 tonnes per day, the conveyor has to feed the sugar cane continuously to the Mills. To avoid jamming at the cutter, leveller, crusher and to avoid choking of the Mills, the conveyors must operate at a uniform loading. It is advisable to prevent any irregular loading on the conveyors. In case of choking of the first mill, it is necessary to reduce the conveyor speed.

For efficient operation, the conveyors must be equipped with variable speed drives. Earlier the conveyors were driven by AC commutator motors, the speed of which could be adjusted conveniently by shifting the brushes. Due to economic reasons, as well as for the maintenance problem of the brushes, commutator motors have been replaced by Totally Enclosed Slipring Induction Motors. The inherent characteristics of slipring motors, with high starting

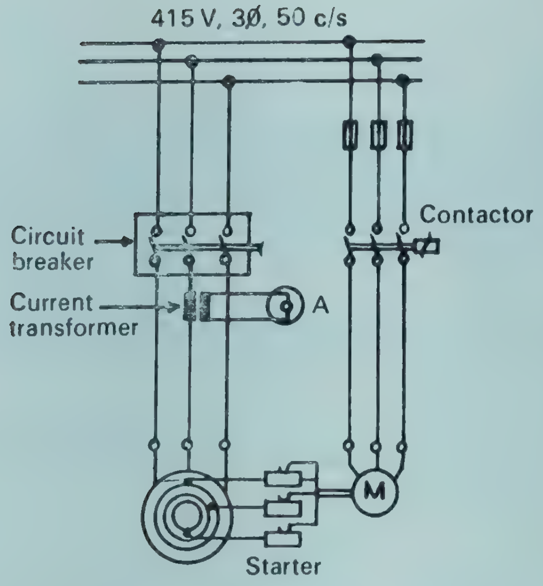


Fig. 2 Schematic diagram of Slipring Induction Motor with Starter

torque and high pull-out torque, are well suited for conveyor drives. The latest trend, however, is to employ DC motors with thyristor controls which have stepless speed control.

Cutter and Leveller

The function of the cutter is to cut the sugar cane to the required size with the help of knives. The number of cutting knives or blades are dependant on the crushing capacity. The cutting knives are fixed over the conveyor, and they rotate at constant speed.

Three phase alternating current induction motors have fairly constant speed. Hence, the cutters are equipped with induction motor. For 1,500-2,000 tonnes/day crushing capacity, a cutter is normally provided with 48 knives and is driven by 200 hp-250 hp, 3 phase slipring induction motor of 580 rpm.

The function of the leveller is to level the cane blanket or layer with the aid of the knives. These levelling knives are also fixed on the conveyor system. The arrangement of the levelling knives and the cutting knives vary from factory to factory. Normally, the levelling knives are arranged first and the cutting knives later. In some factories the procedure may be vice-versa. The levelling should be uniform so as to prevent the short-time overload on the cutter. For this size of plant a leveller is normally equipped with 48 knives and is driven by 200-250 hp, 3 phase slipring induction motor having a speed of 580 rpm.

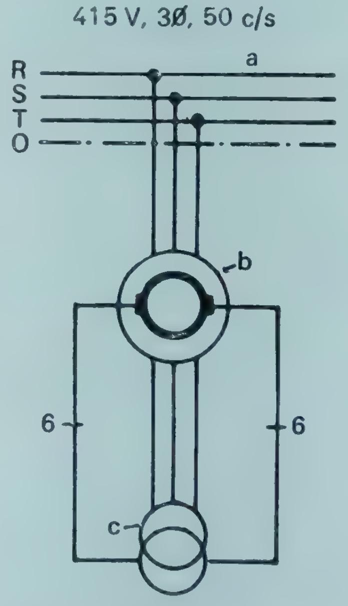
Crusher

If the cane chips are properly cut into the required sizes by the Leveller and Cutter, there is no use of having the crusher. Sometimes a crusher is installed before the first mill to further reduce the size of the cane chips. The crusher will break the bagasse to a coarse size, which will be further broken into subsequent mills for the better extraction of the juices.

The crusher is driven by 200-250 hp AC slipring induction motors suitable for 580 rpm.

Mills

The milling plant consists of four or five mills, which are arranged one after another in a tandem. Each mill has three grinding rollers. The rollers have different cross-sections. For this size of plant the rollers have approximately 800 mm × 1500 mm size. Each mill is driven by a single steam engine or turbine having an output of approximately 500 hp. The engine is operated at different speeds. Normally lower speeds for the 1st and 2nd mills and slightly higher speeds for subsequent mills. The grinding rollers are driven through reduction gears and operate at a speed range between 3.5 to 6 rpm. The grinding rollers press the sugar canes at a pressure



a Three phase system
b Three phase series commutator motor
c Intermediate transformer

Fig. 3 Simplified basic circuit of a three-phase motor with 12 brushes

between 100-500 tonnes. The normal practice is that rollers have different grooving or profiling. The size of the grooves is reduced from the 1st mill to the last mill. Hence, it is desirable that the pressure should increase towards the end of the milling plant. There is a gradual reduction in clearance between the rollers, which in turn increases the slip between the rollers and the cane carriers. It is the customary practice to drive the roller sets at different speeds, i.e. the speed is normally lowest for the 1st roller set and the highest for the last set of rollers. The speed difference is normally .4 to 1 rpm. For example, when the 1st roller set has a speed of 3.2 rpm the last set of rollers will have speed of 3.9 rpm.

The adjustment of roller sets varies from factory to factory depending upon the conditions in which they have to operate. This speed adjustment ensures that mill efficiency is maintained at a constant speed.

The grinding roller sets are either operated at a common speed, i.e. the same speed for all the roller sets of the entire milling plant or operate at individual speeds. Where the roller sets operate at a common speed the speed adjustment range of $\pm$ 25% would be sufficient.

The individual speed control has the advantage of speed adjustment required for different roll diameters and to provide various roll speeds—either to increase or decrease, from the first end to the last end of the roll. The speed range of $\pm$ 10% would be sufficient.

On the basis of these two speed ranges (one for common speed, another for individual speed) it is possible to have an identical design for primary and secondary gear units.

As stated above, the speeds and the pressure will be gradually increased towards the end of the milling plant, so the ratings of the engine should be properly selected.

Though the majority of the Sugar Milling Plants in the world are provided with a steam turbine system, the trend has already started for the switching over to the electric driving system. Various types of electric drives have been adopted for milling plants. These will be briefly reviewed in the later part of this article.

In the mills, the cut cane is finally crushed and the extraction of the juices is nearly complete except for the slight recovery of the juices from the bagasse by maceration system. This maceration system has one defect in that the mills may sometimes get clogged; which occurs when the rolls rotate without moving the cane carriers. The cane blanket then piles up in front of the 1st roller set. To prevent this clogging it is advisable that the roller should rotate in the reverse direction at a uniform speed until the piling up of the raw material is cleared. For electric driven systems there is no difficulty in getting into the reverse direction since the main drive is normally reversible. Where the main drive cannot be made reversible, an auxiliary drive, with a reversible direction, is incorporated along with the main drive. A schematic diagram of the various drives has been shown in Figure 1.

Pumps

Under the mill, the juices are collected in juice tanks, The function of the pump is to feed the juice into the next process, i.e. for clarification. Pumps are normally centrifugal, driven by conventional squirrelcage induction motors which operate at 1500 rpm.

Consideration for Electric Drives

As stated in the foregoing, the Mills are normally driven by steam turbines either by single drive, or by group drives in tandem. Earlier consideration to employ turbines was mainly from the point of process operation, where steam is required for processing and secondly for the utilisation of bagasse, which is fired as fuel. Hence, turbo sets are commonly used for the supply of power to the sugar factories.

On account of the availability of various types of electric drives with efficient control systems during the last decade, many sugar factories have opted for electric drives instead of the conventional steam drives. Apart from the merits of the electric drive system, economic reasons also led to the switch over to the new system. Some advantage of the electric drives are enumerated below :

(1) The capital cost of the electrical equipment is much lower than that of the steam turbine system.

(2) Considerable saving of space due to the elimination of steam piping.

(3) Curtailment of complicated civil engineering work, since only a small foundation is necessary for the electric drive.

(4) Reduction in steam consumption by using a large turbo-generator set with a low steam consumption, instead of several small turbines or steam engines with a high consumption. Back-pressure turboset is commonly used for the power supply.

(5) Cleaner surroundings and absence of disturbing noises.

(6) Future extension of the plant can be taken up without difficulty.

(7) The requirement of operating and maintenance personnel is brought down to a minimum.

(8) Local and remote control system is attained with the electrical drive. It is feasible to obtain loss-free speed control and better efficiency over the entire speed range.

(9) Reverse-direction operation of the mill can be done easily so as to prevent clogging and piling up of the raw materials.

Various Types of Electric Drives

Various types of drives employed for the operation of the Mills are stated below :

(a) AC slipring induction motor with rotor control device.

(b) Three phase commutator motors either with series or shunt characteristics.

(c) Ward Leonard Set.

(d) Cascade System.

(e) DC Shunt motor.

AC Slipring Induction Motor

Three phase alternating current slipring induction motor can be used for the mill drive. The basic circuit diagram of the drive is shown in Figure 2.

The slipring motor with the variable resistor in the rotor circuit enables not only the starting but also provides the speed control. Since the speed of the motor depends mainly on the series resistor, apart from the load, care should be taken for the proper selection of the external resistor. For a sugar mill of 2,000 tonnes crushing capacity the individual mill requires a motor of 500 H.P. to be operated either at 600 rpm or a maximum speed of 750 rpm (Syn.). For this size of motor, normally a liquid starter is to be employed for the starting of the motor, in addition to the series resistor for speed control.

A slipring induction motor is the cheapest electrical drive for the mill and can be operated without any complicated control system. It has certain limitations, particularly when the motor has to operate at very low speed. The motor loses its shunt characteristics with the increase of resistance in the rotor circuit. The speed becomes largely dependent on load. Since the mill has to cope with the load between zero and overload, a constant speed could only be maintained by continuously switching in and out of the resistors in the rotor circuit. This is not a practicable proposition, since this would involve a considerable power loss. The lowest speed can be obtained only upto 50% of the rated speed. Even then, there will be considerable loss in the rotor circuit, which is wastage as heat loss.

Three Phase Commutator Motor

To obtain a good speed regulation, it is desirable to use a three phase commutator motor. The operating condition of the commutator motor is practically the same as the slipring induction motor, when operated at a synchronous speed, i.e. synchronous speed less slip. But at 50% of the rated speed the commutator motor is more stable than a slipring motor as the speed change will be 1% instead of 10% for slipring motor for the same amount of load torque. Another important aspect is that, with the commutator motor, it is feasible to attain a loss-free regulation.

For the mill drive, it was thought that the shunt wound commutator motor would be ideally suited, due to its shunt characteristic, which is independent of load. The cost of the shunt wound commutator motor is much higher than that of the series wound commutator motor, for the same output. Hence, series wound motors are preferred. However, suitable

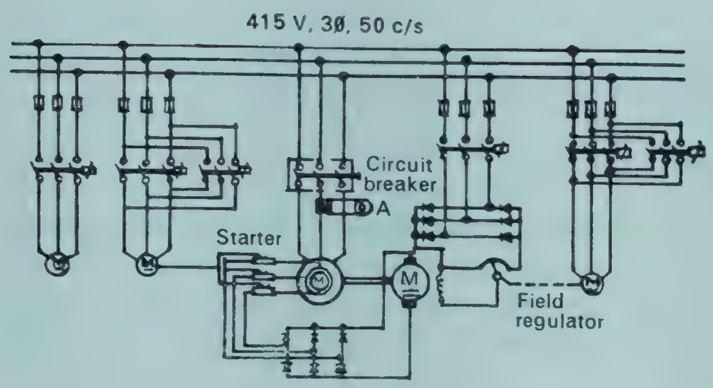


Fig. 4 Schematic diagram of Cascade system

controlgear must be provided to cause the motor to operate with a shunt characteristic.

The shunt-wound commutator motor can be either stator fed or rotor fed. The construction of series wound motor is basically the same as the statorfed shunt wound motor. As such the series wound motor does not require starter during starting, and the speed can be varied through its full rated range. The arrangement of the connection diagram is shown in Figure 3.

The stator of the series commutator motor is connected to the 3 phase supply. The other terminals of the stator are connected to the primary of an intermediate transformer, the secondary of which is connected to the rotor through brushes. The intermediate transformers are of the dry type and are located near the motors. They fulfil the required parameters so that the commutator can be designed for suitable current-voltage ratio.

The motor can be started at different steps with reduced torque and is also suitable for starting against load torques equal to multiple of the rated value.

As stated earlier, the motor has better stabilization of the speed, consequently the better control characteristics. By adjusting the position of the brushes the different speed can be obtained. The running and starting torques increase when the brush-rocker moves in the direction of short-circuiting position.

Each mill is driven by a 500 hp. series wound commutator motor in conjunction with reduction gear units in tandem. The maximum speed of the commutator motor is 1000 rpm having a normal speed range 1 : 3. The rated full load torque is obtained between the speed range 500 and 1000 rpm, 75% of rated torque is achieved between the speed 330 to 500 rpm. Higher starting torque upto 200% can be obtained by shifting the brush rocker position. The motor can be operated in either direction of rotation so as to clear the mill during clogging.

The motor has definite advantages over the steam engines and slipring induction motor in respect of speed control, the speed variation 1 : 3 is practically loss-free. The power requirement of the mill is much less with the motor driven system compared to steam engine. In other words, the tonnage of cane crushing can be increased considerably for the same power required by the engine.

Ward Leonard Set

The DC motor with Ward-Leonard control system is selected as one of the drives, for the Mill. The basic principle of operation is the speed control by variation of the armature voltage of the motor. A separately excited DC motor is employed for mill drive, whose speed can be controlled from zero speed to rated speed. This DC motor is driven by a motor-generator set (AC motor with DC generator). The armature voltage of the DC generator can be altered from zero to maximum, in either direction by varying the excitation. This generator in turn varies the armature voltage of the DC motor coupled with the mill drive. The speed of the DC motor can be changed with the armature voltage of the DC generator. The rate of speed change thus achieved has the same percentage with all the mills, however, the speed ratio remains unaltered.

This system has unique advantage for attaining a fine control over a wide range of speed and it is also feasible to obtain a small change of speed with varying load. The only limitation which prevents the use of this set is low-efficiency compared to the other type of drives.

Cascade System

A Cascade unit is essentially a combination of AC slipring induction motor and DC motors. A schematic diagram of cascade system is shown in

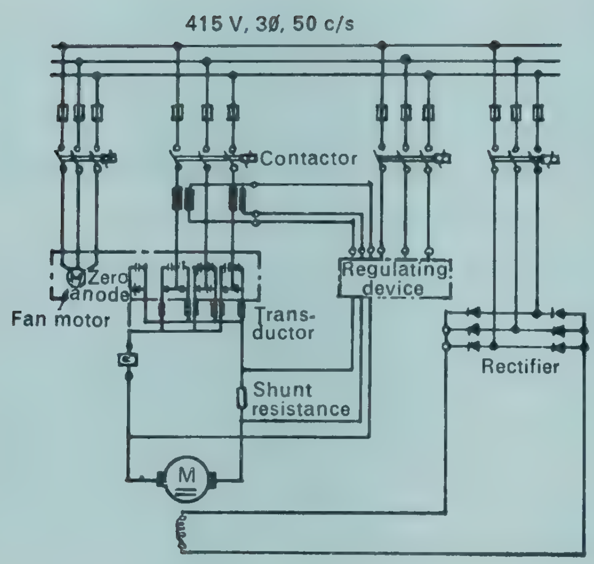


Fig. 5 Schematic diagram of DC Shunt Motor with Transductor Control

Figure 4. Slipring induction motor is employed for the mill drive. The armature of the DC motor is connected to the rotor of the slipring induction through the rotor starter and rectifier and operates on the utilisation of slip-energy. The slip power of the mill motor is rectified into DC power, which in turn is transformed into useful mechanical work by the cascade DC motor. The DC motor is coupled with the shaft AC motor.

The control of the speed is achieved through the excitation of the DC motor. With this system it is feasible to obtain a speed variation to the extent of 50% of the rated speed, independent of the load torque. When DC motor is not excited there is practically no armature voltage, except the residual voltage. Hence, the power of the AC motor will bring the high speed. As soon as the DC motor is excited the armature voltage rises, the speed of the set will fall. A balanced system will reach when the slip voltage is equal to the rectified voltage. At the full excitation of the DC motor, the set will attain 50% of the rated speed and the rating of the DC and AC motor, each, will be half the capacity.

The starting torque upto four times of the rated full load torque is obtained. A starting resistance is incorporated in the rotor circuit, which is gradually cut off from the circuit during starting.

This cascade system provides a stepless and loss-less regulation compared to the slipring motor, but it has one demerit-low power factor.

DC Shunt Motor

For the mill drive, DC Shunt motor can be employed, since the motor possesses an inherent characteristic of high starting torque. The speed control can be attained with the aid of a suitable regulating rectifier device.

The DC mill motor can be fed from silicon rectifier with magnetic-amplifier control or transductor control. The silicon rectifier set of the transductor comprises of a three phase bridge connected cell in a zero anode. A three phase rectified power is fed to the DC motor. The field excitation of the motor also receives the DC power from the supply network through a small rectifier system. The schematic diagram of the DC motor with transductor control is shown in Figure 5.

The transductor provides the speed regulation. The saturation of the individual transductor coil will define the required amount of control current, this will set the division of voltage between the transductor and the motor. The transductors are so designed that they can block the entire armature voltage.

This system provides maintain free, quick and sensitive speed regulation and the efficiency is better than motor generator set. The cost of the equipment is comparatively higher than any other device so far described. It is also possible to use grid-controlled mercury arc rectifier instead of silicon rectifier.

Conclusion

Various types of electric drives have been contemplated for the mill drive instead of steam turbine or engine. Amongst these drives, the series-wound commutator motors have already been employed in many cases and the same are found to be economical and efficient from many respects.

DC motor with thyristor control is gaining momentum and for many industrial drives same have been used. The application of DC motor with thyristor control might be considered as the mill drive in the near future.

NUMERICAL CONTROLS FOR MACHINE TOOLS

—J. GEHRELS AND J. BÖHME

Introduction

Numerically controlled machine tools are ideal for the economical machining of workpieces required in small or medium-sized batches. However, they are also being used to an increasing extent for very small batches and very large batches, Figures 1 and 2. In 1972, Europe had a total of 13,000 numerically controlled machine tools. If the present rate of increase continues, this figure will have doubled by the end of 1975.

The growing demand for numerically controlled machine tools reflects the progress made. Typical standard applications include turning, boring, drilling and milling. More specialized applications are nibbling and flame cutting. Moreover, numerical controls have found their way into other fields such as grinding, forging and woodworking.

One of the main aims in employing numerically controlled machine tools is to reduce the machine times and down times and thus to cut manufacturing costs. Another major factor, however, is the consistently high workpiece quality obtainable on numerically controlled machines. A further point that should not be overlooked is that numerically controlled machines permit skilled workers to be replaced by semi-skilled workers. Going a step further, labour costs can be reduced appreciably by having one operator mind several machines.

To obtain maximum benefit from the possibilities of numerical controls, it is essential to make sure that the capacity of modern machines is utilized fully. Special account is taken of this in the design of the SINUMERIK numerical controls manufactured and marketed by Siemens. SINUMERIK controls combine simple operation and programming with functions that ensure optimum machine utilization. Such functions include high resolutions at high traversing speeds and extremely short acceleration and braking times obtained through a constant torque selected to suit the machine. SINUMERIK permits the correction of complete machining programs on the machine itself. This shortens the test times and production start-up times of workpieces that have been programmed for the first time.

The economic efficiency of numerically controlled machines is determined to a large degree by the reliability of the numerical controls themselves. In

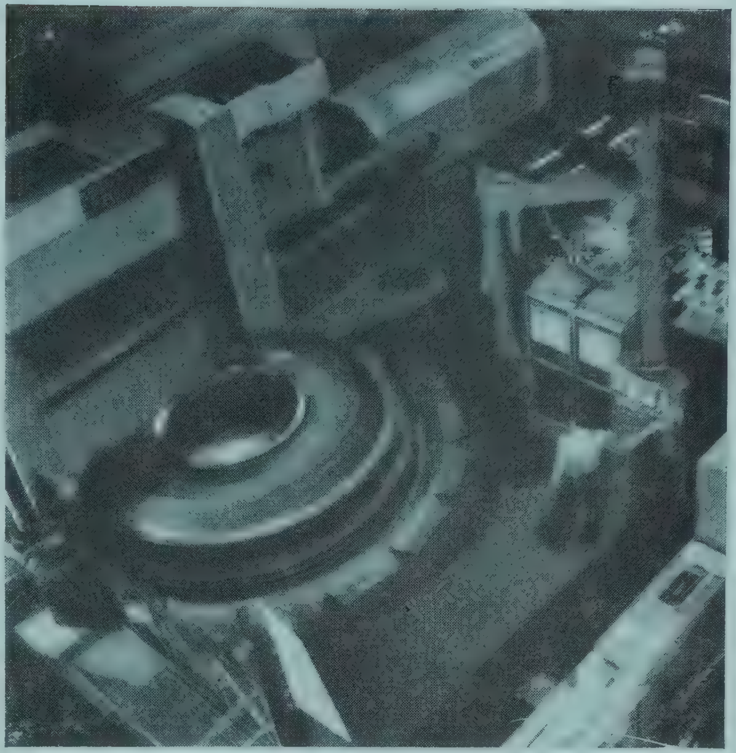


Fig. 1 Numerically controlled lathe for the machining of individual parts

the SINUMERIK controls, this is obtained by compactness and the provision of an extensive monitoring system to enable faults to be detected at an early point and to prevent damage to machine or workpiece. Monitoring devices are provided for the measuring system, the drives, the temperatures and the voltages.

The SINUMERIK 520 K, Figure 3, for lathes and the SINUMERIK 550 C for boring, drilling and milling applications are two controls in which special attention has been paid to reliability and economic efficiency. Let us now take a closer look at some of the typical functions of these controls.

SINUMERIK 520 K

The SINUMERIK 520 K is a continuous-path control for lathes equipped with continuous servomotors. The basic functions of the SINUMERIK 520 K conform to the international standards for lathe controls :

Two axes, linear and circular interpolation

Buffer stores

Punched tapes and manual input to EIA or ISO

Programming in address format with variable word and block length

Fig. 2 Lathes for large batch production

Absolute and incremental data input

Feedrate and rapid traverse override

14 tool compensating switch pairs

Floating zero

Thread cutting 0.002 mm to 40 mm lead

Feedrate 0.1 mm/min to 4000 mm/min

Rapid traverse up to 12 m/min

Input resolution 0.001 mm

Output resolution 0.002 mm

Synchro or INDUCTOSYN scale for measurement.

The high computing accuracy of 0.001 mm and the wide feedrate range of 0.01 to 4000 mm/min ensure maximum accuracy and optimum surface quality of the workpiece.

While the importance of such basic functions must not be overlooked, it is true to say that there are other numerical control characteristics that are more decisive for both machine tool manufacturer and user. It is here that the SINUMERIK 520 K comes into its own.

Function G95 " Feed per revolution", for instance, enables the path feedrate to be programmed in mm per revolution of the main spindle instead of in mm/min. This enables the programmer to compile his program according to the chip thickness. It is thus not necessary to convert the feedrate on changes in spindle speed. Function G96 " Constant cutting speed " permits the cutting speed, i.e. the speed of the workpiece surface referred to the tool tip, to be programmed direct in m/min under address S. Here, the speed of the main spindle is set automatically as a function of the turning diameter to maintain the cutting speed constant at the set value.

The functions " Feed per revolution " and " Constant cutting speed " not only permit optimal utilization of the machine, but also provide high quality of the workpiece, even on plain faces and large tapers.

Further interesting features of SINUMERIK 520 K are program correction and the sub-routine system.

Workpiece programs compiled for the first time are never optimal and always require correction for material or geometry. This makes it necessary to change the program after the test run. On the SINUMERIK 520 K, program changes are fed by hand into a program correction store. The great advantage of program correction on the SINUMERIK 520 K is that it is not necessary to store the entire workpiece program, but only the part to be corrected. Thus it is possible to correct machining programs of any length by storing the correction values under the particular block number. Corrections stored in this way are inserted into the program read in from the punched tape or inserted into the program taken over by the program store described below. A store for 1000 punched tape characters is available for the corrections.

Program correction includes the following :

Correction of single words in a block

Cancelling of single words in a block

Insertion of new words in a block

Cancelling of a block

Replacement of a block by a new one

Insertion of a maximum of nine new blocks between two blocks

Correction of a correction.

An example of program correction is shown in Figure 4. After the correction values have been read in, a workpiece can be machined with the uncorrected punched tape without shutting down the machine. Correction of the punched tape for filing can be carried out in the programming office when con-

venient. However, corrections are also possible during subsequent machining. Primarily these will involve such values as feedrate or spindle speed that have to be adjusted to suit the material to be machined.

Storage capacity remaining after a program correction can be used for one or more programmable subroutines or program parts fed in via punched tape or by hand. These subroutines or program parts can be called in as often as required during the program by means of punched tape commands or manual commands. Hence, programming is simplified considerably. Possible subroutines include :

Cutting sub-division

Recessing cycle

Thread cutting cycle.

It is also possible via punched tape or manual input to feed complete machining programs into an additional store with a capacity of up to 7000 punched tape characters. Machining can thus be carried out without punched tape control. The stored program can then be called in without waiting time for the next workpiece, Figure 4.

With these stores for corrections, subroutines and complete machining programs, the SINUMERIK 520 K is suitable for very small batches (the program correction facility direct on the machine enables production to be started quickly) or for very large batches (storing of the complete machining program and thus no wear on the punched tape).

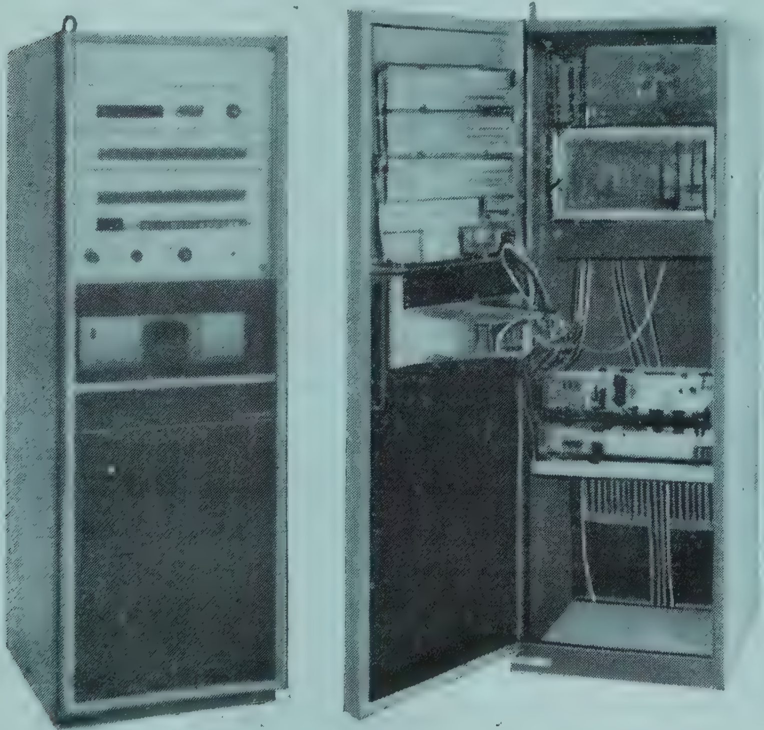


Fig. 3 SINUMERIK 520 K

SINUMERIK 550 C

The SINUMERIK 550 C—continuous path control in up to 4 axes with punched tape and manual input—is intended for the numerical control of boring machines, drilling machines, milling machines and machining centres equipped with continuous servomotors. Here too, Siemens have provided functions that extend beyond international standards and which leave little to be desired from the standpoint of the machine tool manufacturers and the users :

Four axes, linear and circular interpolation

Buffer stores

Punched tape and manual input to EIA or ISO

Programming in address format with variable word and block length

Absolute and incremental data input

Full circle programming

Feedrate and rapid traverse override

99 tool compensating switch pairs

Cutter radius and path compensation

Thread cutting at leads of 0.001 mm to 50 mm

Feedrate 1 mm/min to 10,000 mm/min

Rapid traverse up to 15 m/min

Input and output resolution 0.001 mm

Traversing range 79 m

Two floating zeros per axis

Synchro, INDUCTOSYN scale or digital linear measuring system

Program correction for 1000 punched tape characters

Program stores for 10,000 punched tape characters

Subroutine system for parameter programming.

These functions make the SINUMERIK 550 C suitable for almost every type of boring, drilling or milling machine.

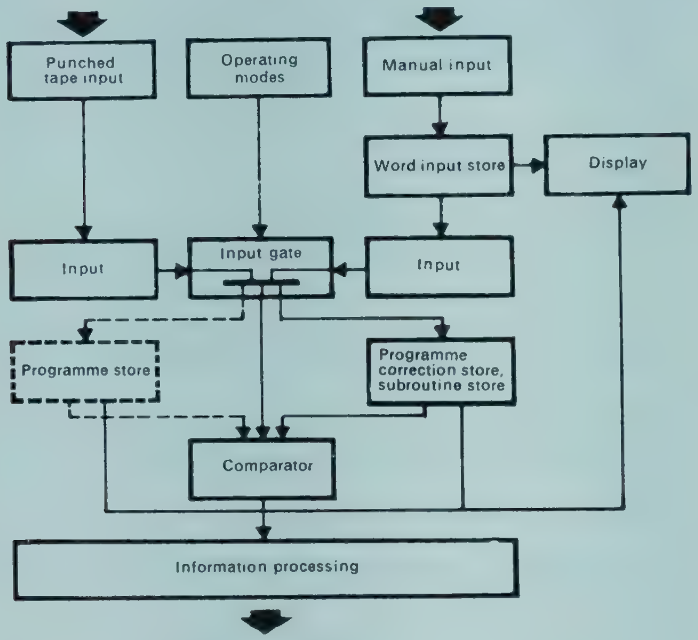
A particularly interesting feature of the SINUMERIK

Uncorrected programme

: 10	G00 X 500 F 50	S 12	LF
N11	G01 Z 500 F200	T101	LF
N12	F500		LF
N13	G00 Z–100	S 13	LF
N14	G04 X1000		LF
N15	G01 X–120 F200		LF

Correction data

N11		Z 400 F/		LF
N12		X 250		LF
N1012		X 400		LF
N2012		X 500	S 14	LF
N13	G01	F100	S/	LF
N15	G/	X/ F/		LF
N11		Z 400 F/	T102	LF



Corrected programme

: 10	G00 X 500 F 50	S 12	LF
N11	G01 Z 400	T102	LF
N12	X 250 F500		LF
N1012	X 400		LF
N2012	X 500	S 14	LF
N13	G01 Z–100 F100		LF
N14	G04 X1000		LF

Programme correction and Programme store

Explanations:

Block N11:
Correction of individual words (Z), cancelling of individual words (F)
Identification by block No.
In the case of G and M functions, all G or M words are fed in anew if correction is required.

Block N12:
Insertion of individual words (X)
Identification by block No.

Block N1012, N2012:
Insertion of new blocks
Identification by 1 to 9 in front of the 3 digit block No. of the preceding block.

Block N13:
Replacement of a block.
Identification by block No.
Correction, cancelling and insertion of the individual words.

Block N15:
Cancelling of a block
Identification by block No.
Cancelling of each individual word.

Block N12:
Identification by block No.
The previous correction is not effective.
All corrections contained in the last correction input must be repeated.

Fig. 4 SINUMERIK 520K example of program correction and program storing

550 C is the subroutine system with parameter programming. The subroutines may consist of standardized drilling cycles or complete repetitive programs, e.g. for drilling patterns, milling patterns or tool changing cycles. Up to 99 subroutines can be fed in via punched tape. These are not lost in the event of voltage failure. In addition to the fixed values of a subroutine, it is also possible to feed into the store up to 10 parameters whose numerical values are then set in the main progarm by programming in the punched tape.

Figure 5 shows the possibilities of this subroutine system by way of the milling of rectangular cut outs.

Generally the machining of these rectangular cut outs is described by four parameters, the two side lengths (R0 and R1), the corner radius (R3) and the feed of the milling tool in the Z axis (R2). The subroutine, which is stored and only programmed once, consists of 11 blocks in which the four parameters R0, R1, R2 and R3 are in each case programmed with the correct sign after the corresponding axis address.

Call-up in the main program takes place under address L with the subroutine number, in our example in blocks 27 and 29 under L 46. Here, the parameter values are programmed under addresses R0, R1, R2 and R3 with the particular dimensions and without signs. Parameters that remain the same, need not be programmed again. Thus if only one side length of the rectangular cut out is changed, only the associated parameter must be newly defined. In our case R0 changes from 200,000 in block 27 to 130,000 in

block 29. This permits free modification of a given machining pattern whose programming scope is reduced to a fraction of the original scope.

Feed and Spindle Drives

The capacity of a machine tool is not only determined by the design of the numerical control, but also by the drives provided. Since normal d.c. drives are unable to cope with the demands made by modern machine tools, Siemens have developed new feed and spindle drives.

An outstanding feature of the Siemens feed drives is the dynamic performance which permits minimum starting and braking times. The high maximum speeds possible allow rapid traverse speeds of up to 15 m/min. Speed ranges of 1 : 10,000 to 1 : 30,000 cater for all required feedrates. Thus it is possible to cover the entire feedrate range continuously without gear changing. These properties mean that machine designs can be kept very simple.

Siemens have developed drive units for spindles which not only provide continuously variable speed, but also incorporate other functions of vital importance in machining operations. These include devices for constant cutting speed, and for sensing and monitoring of actual speed and current. Other examples are selectable current limiting for smooth braking or the skipping of braking on small speed changes in order to improve the quality of the surface on parts being turned.

Main programme

```
N27   L46 (R0) 200000 (R1) 100000 (R2) 30000 (R3) 25000   LF
N28   X70000   Y 200000 LF
N29   L46 (R0) 130000 LF
```

Subroutine

```
L46     LF
N4601   G01   Z− (R2) LF
N4602         X + (R0) LF
N4603   G02   X + (R3) Y− (R3) J + (R3) LF
N4604   G01   Y− (R4) LF
N4605   G02 ...   ...   ...   ...   ...   LF
N4606   G01   X− (R0) LF
N4607   G02 ...   ...   ...   ...   ...   LF
N4608   G01   Y + (R1) LF
N4609   G02 ...   ...   ...   ...   ...   LF
N4610   G01   Z + (R2) LF
N4611         M20    LF
```

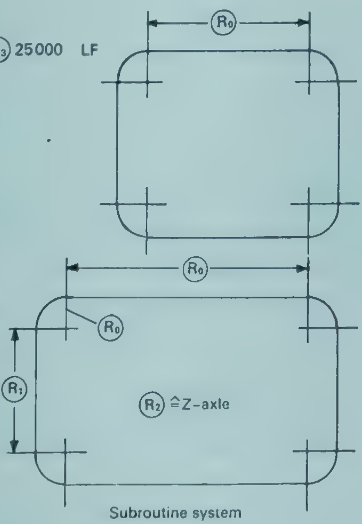


Fig. 5 SINUMERIK 550C example of the subroutine system with parameter programing

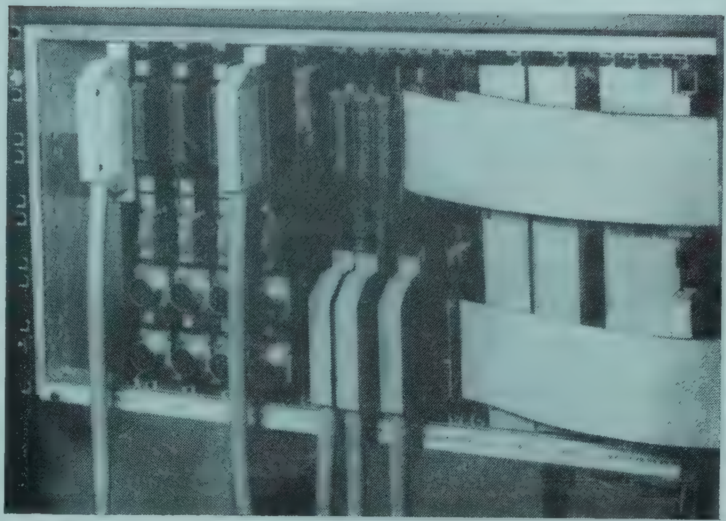


Fig. 6 Logic section of SINUMERIK 550 C

The interaction of the components on a numerically controlled machine is just as important as the function of the components themselves. The SINUMERIK numerical control system and the Siemen s feed and spindle drives are carefully co-ordinated and thus ensure optimal functioning of the entire machine tool.

Conclusions

SINUMERIK numerical controls and Siemens drives are designed to permit simple commissioning and servicing.

For instance, the SINUMERIK control can be adapted to the machine parameters by a few simple adjustments. Wide use is made of digitalizing in the speed and mesuring circuit. The speed gain in the positioning control circuit is set commonly for all axes. Servicing is simplified by the fact that the contents of the information stores can be shown on a universal display. Internal information processing in the logic section can be followed step by step. The functional groups, such as logic frame, operating control panel and reader are connected by plug-in cables. Parts subject to wear are of the plug-in type and are easy to change. Both the logic section of the SINUMERIK 520 K and that of SINUMERIK 550 C, Figure 6, consist of a few easily accessible printed-circuit boards. The amount of spares to be stocked is thus kept to a minimum.

FEED DRIVES FOR MODERN MACHINE TOOLS

—A. GULATI

Rising production costs and the need for more complicated jobs have necessitated the rapid development and automisation of machine tools. This was mainly so, because the jobs had to be finished faster and with closer tolerances.

A large number of automobile and aircraft parts, because of their low weight, are being made with light alloys. These alloys allow feed rates upto 10 m/min. Also, for steel and cast iron, higher feed rates can be obtained by the use of newly developed materials for the cutting tools. To achieve this, the machine tool had to be greatly improved, not only mechanically but also electrically. Greater precision was achieved with the help of electronic closed loop control systems, such as Numerical Control Systems, and faster slide movements with the help of the newly developed DC motors—the DC servomotor, as the normal DC motors could not be adapted for the modern machine tools. The older version of using AC motors with gear-boxes and electromagnetic clutches could not fulfil the requirements anymore. The speed was not continuously variable and the number of speed steps was limited. In this article we are going to discuss only the feed drives.

Demands on the Construction of the Machine Tool

The machine tool must be very rigid in construction and the guide rails must be exact. The feed drive consists not only of the motor but also includes the reduction gear and the ball screw spindle and nut combination. Play and elasticities in these parts reduce the quality of the whole drive and therefore of the machine tool.

The feed drive should be made compact, with a low moment of inertia and without play. Each axis should have its own drive which is mounted directly at the spindle.

In machines where only one axis is traversed at a time, the earlier design of using only one drive with electromagnetic clutches and a long series of gears or belt drives is no longer acceptable. The high moment of inertia, the additive play in the gears, and elasticity of the gears and bearings make it impossible to make full use of the good dynamic characteristics of the feed motor.

Fast feed drives are not only important for copying machines or NC continuous path control, but also for simpler machines. For example, with fast speed drives the time required to travel to a given point, calculated from the first speed reduction, can be reduced from 20 sec. to 0.5 sec.

Demands on the Feed Motor

The progress and development in certain branches of industry, such as the automobile and aircraft manufacturing industries, call for the machining of complicated jobs within very close tolerances. To get the proper surface finish, the cutting speed selected has to be the optimum speed for the particular material, type of cutting tool and the operation, whether coarse, fine or polishing, i.e. the feed drive has to be of a continuously variable speed type.

The feed drive must be designed for four quadrant operation, i.e. accelerating and braking in both directions, with immediate torque reversal from acceleration to braking and vice-versa. For NC continuous path control also with immediate and continuous transition from one speed direction to the other, i.e. the feed rate has to be continuously regulated down to zero and then accelerated again in the opposite direction, with the tool engaged.

A constant torque over the whole speed range is a must; for example when a miller cuts along a contour, load changes due to a change in the cutting depth (when cutting along an inclined or curved contour), or due to inhomogenities in the workpiece, should not affect the motor speed. In machine tools of older construction a large part of the feed power is converted into heat due to the low efficiency of the numerous gears and spindles, and the sliding friction of bearings and guide rails. As an improvement to the older version, in newer constructions, DC drives with single step reduction gear, ball screw spindles, hydrostatic bearings for the slides and supports are used. Thus, a maximum constant torque can be transmitted with a minimum of heat losses.

In order to keep repeat traverse times to a minimum, higher rapid traverse speeds are required. This was

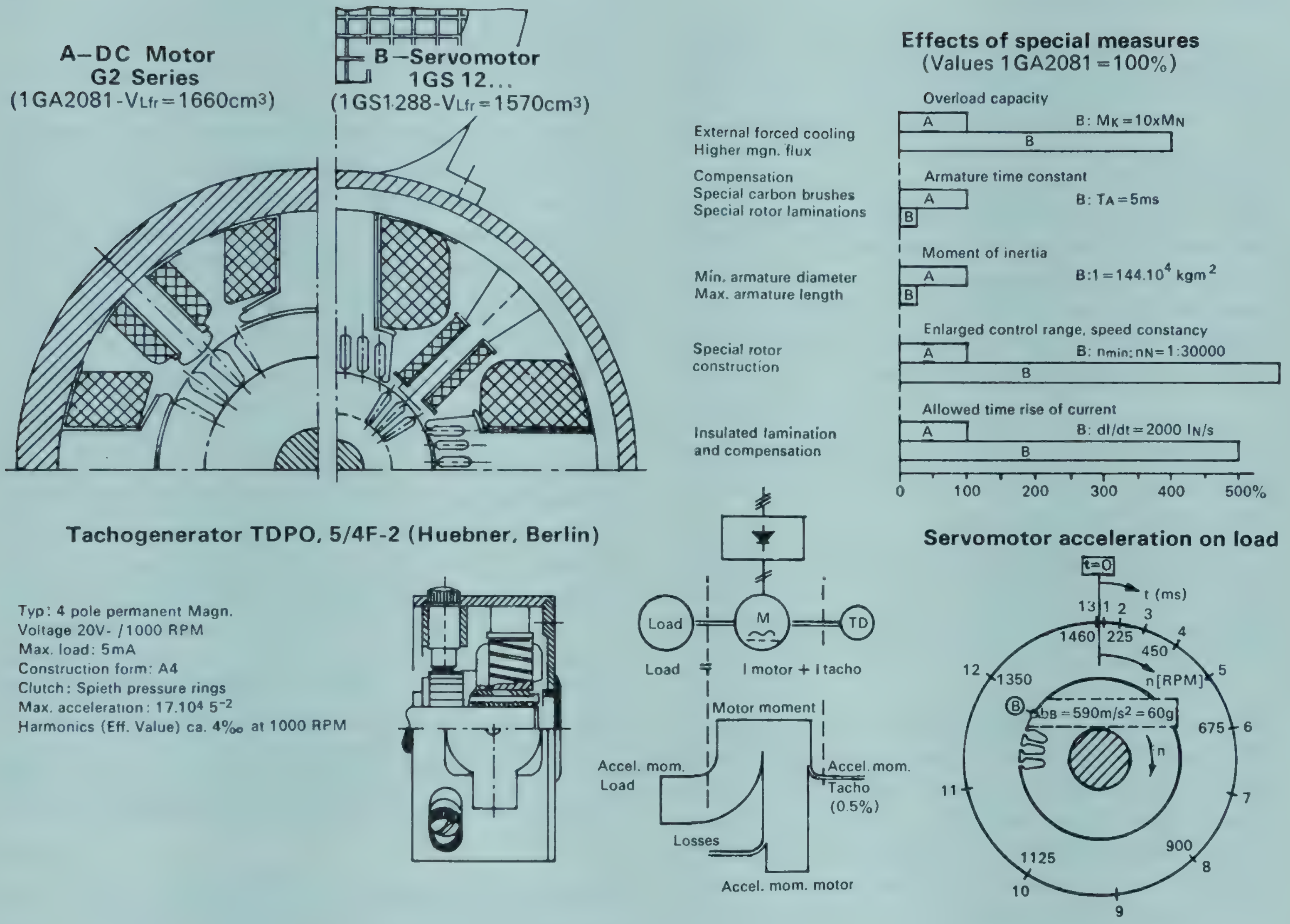


Fig. 1 Comparison of a normal DC motor with a DC Servomotor

previously done by changing the gear ratio between motor and spindle. However, the switchover time required for the gears offsets the time saved due to the higher speed, especially for shorter distances. Therefore, the maximum motor speed should be large enough to give the required rapid traverse rate without having to change the gear ratio.

Very small speeds (creep speeds) are also required to travel exactly to a predetermined point without overtravel, independent of how this end point is set or coded—by limit switches or by a closed loop positioning control.

The demands on the feed motor are therefore :

(i) Large speed range.

(ii) High speed constancy also at low speeds.

(iii) Constant torque over the whole speed range independent of load changes.

(iv) High acceleration and braking torques.

(v) Short regulation times, also when large speed jumps are desired, i.e. a very good dynamic response.

Normal DC Motors

The above demands cannot be met by an AC motor. Hydraulic and electrohydraulic motors were often used as they were capable of giving a constant torque but the speed range was limited and the construction very bulky. Here, only DC motors with armature control and constant field excitation comes into consideration. The control unit can be a Ward Leonard MG set or a thyristor converter. Thyristor converters are preferred because of their better efficiency, faster response, easier installation, lower noise level, and practically maintenance free service.

With an open-loop speed control, speed ranges of upto 1 : 30 can be achieved. This is sufficient for the normal working feed rates but not enough for the rapid traverse or creep rates.

A closed loop speed control with a thyristor converter can give speed ranges upto 1 : 1000. The maximum motor speed of the DC motors for these purposes is about 4000-6000 rpm. A gear-box is no longer required, a single step reduction gear is enough, which is so layed out that the maximum motor speed corresponds to the rapid traverse speed. Though this system is comparatively expensive, the higher cost is offset by the simpler mechanical construction. Hence, the dynamic response of the machine tool is greatly improved. It accelerates and brakes much faster, thus lowering the time required to finish a job.

With a given spindle thread pitch, the reduction gear ratio is obtained through maximum motor speed and required rapid traverse rate. The motor speed corresponding to the maximum feed rate lies at a much lower speed, at which the dynamic characteristics of the drive are much better, since the effect of the moment of inertia reduces with the square of the speed. The armature voltage determines the motor speed, therefore, the armature voltage corresponding to the feed rate is much lower than that at rapid traverse. This voltage difference acts as a reserve voltage for large speed jumps and to compensate for the time constant of the motor.

The feed motor must have an external cooling fan. Thus, the cooling is independent of motor speed and therefore, the motor is capable of giving full rated torque even at speeds near zero without overheating. This also increases the accelerating moment to moment of inertia ratio, thus giving shorter acceleration and braking times.

With the increase in the speed range, the demands on the tacho-machine also increases. For greater accuracy the speed-voltage characteristics should be as linear as possible, with only a minimum ripple voltage content. The mechanical connection between motor and tacho should give a vibration and play-free operation. The tacho is mounted directly on the motor shaft (non-drive end) by means of pressure rings.

DC Servomotor

The demands set on feed motors by NCs—high acceleration and braking torques and low regulation times—could not be met by normal DC motors. Siemens AG has, therefore, developed a new series (1GS2 series) of DC motors, called DC servomotors which are ideally suited as feed drive motors for machine tools equipped with numerical control systems. Figure 1 shows a comparison between these motors and normal DC motors.

These motors are designed to give an improved dynamic response. A theoretical value of the dynamic quality is :

$$\text{maximum acceleration} = \frac{\text{Max. torque}}{\text{Moment of inertia}}$$

By reducing the moment of inertia of the rotor, the dynamic response of the motor can be improved, but only to a certain extent, as the motor has to accelerate and brake a spindle and tool support both of which have a substantial moment of inertia.

In order to calculate the moment of inertia for the whole drive, the moments of inertia of all the moving parts have to be added to that of the motor. If there is a reduction gear between motor and spindle, then the moment of inertia of the spindle should be divided by the square of the gear ratio :

$$\text{Max. acceleration} \quad \frac{\text{Max. torque}}{\text{I motor} + \text{I gears} + \frac{\text{I}}{\text{N}^2}\text{ spindle} \ldots}$$

I = moment of inertia

N = reduction gear ratio

The maximum speed of the Siemens DC servomotors (1GS2 Series) is 6000 rpm. A spindle pitch of 10 mm and a reduction gear ratio of 4 : 1 gives a rapid traverse speed of 15m/min. The normal feed rates lie in the more favourable dynamic range of the motor (about 1000 rpm). The moment of inertia of spindle and gears, reduced to that of motor shaft, should be, from practical experience, approximately equal to the moment of inertia of the motor itself.

The servomotors have a smaller rotor diameter as that of normal DC motor, see Figure 1, therefore, a smaller moment of inertia. However, the layout of the electrical part is decisive. The commutator and windings allow a short duration current upto 10 times the rated current. The compensation windings in the main poles suppress the armature feedback effect so that the torque also rises proportional to the armature current to 10 times the rated torque. The armature inductivity is kept small so that the armature time constant is very small.

The yoke is insulated laminated. This and the compensation windings, allow a very high rate of change of current which brings a further improvement in the dynamic response of the motor. The DC servomotor also has an external cooling fan which is radially mounted.

With a six pulse thyristor converter the regulation time for speed jumps upto 1000 rpm is approx. 10 ms. The Siemens DC servomotor can therefore accelerate from 0 to 1000 rpm in 10 ms. Already after half a turn the motor has reached this speed, Figure 1. The same holds good for braking, the assumptions being that the thyristor converter can deliver a short duration current 8-10 times the rated current and the external (load) moment of inertia is not substantially greater than that of the motor itself.

Due to elasticities in the machine tool, the high acceleration (positive and negative) of the motor is transmitted delayed to the cutting tool, i.e. they are not in a position to utilise the dynamic response fully. Therefore, atleast for the smaller units, a three pulse thyristor converter is used. The regulation times for these units are 20 ms for 500 rpm speed jumps and 25 ms for 1000 rpm speed jumps.

In either case the motor can still deliver rated torque even at speeds as low as 0.2 rpm. The speed range is therefore 0.2 rpm to 6000 rpm i.e. 1 : 30000. This vast speed range is only possible if all the moving parts are very rigidly attached to each other, the reduction gear should have no play and the elasticities are reduced to a minimum by pre-stressing the spindle.

Considering the above points, it is preferable to use DC servomotors instead of normal DC motors. Numerical controlled lathes, boring and milling machines can be more economically used due to the higher feed and rapid traverse rates. Thus, with servomotors, numerically controlled machine tools achieve not only a better quality but also require less time thus increasing the output of the plant. The simple construction of the thyristor converter reduces the erection and commissioning time and the servicing is reduced to a minimum.

CRIMPING TECHNIQUE FOR ALUMINIUM CONDUCTOR CABLE JOINTING — S K. MITRA

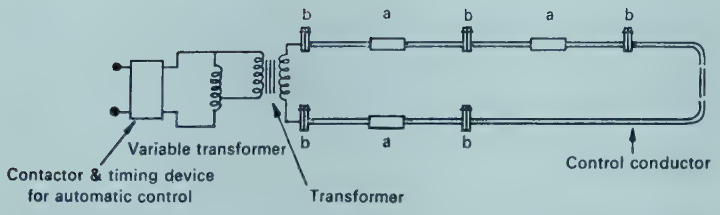


Fig. 1 Through joints—typical test specimen

Introduction

The technique of crimping or compression in jointing of electrical conductors is an alternative method to the already known different methods of soldering and welding. Crimping is a process, where through application of pressure at room temperature, a true metallurgical bond is achieved between the conductor and the terminal lug or ferrule, without undergoing any hot or molten phase.

Crimping is being used extensively and it utilizes an aluminium terminal lug or ferrule filled with a grease-abrasive chemically neutral compound, commonly called " oxidation inhibitor ". When the lug or ferrule is crimped, abrasive particles in the inhibitor cut through the aluminium oxide layer exposing bare metal surface and allow contact to be made between the surfaces under compression. With stranded conductors, the particles are dispersed throughout the strands by the crimping force.

Why Crimping?

The various positive factors in favour of crimping as detailed below have induced the electrical industry to adopt the technique wherever practicable :

(a) Significant reduction in installation man hours and cost of consumables.

(b) Reliable and versatile joints, if dies and indentures used are precision.

(c) Little or no preparation of the metal surfaces to be bonded is necessary.

The crimping technique employs a wide variety of compressing dies and identures developed for several applications differing from one another in number of crimps, shapes and extent of compression. The ultimate effectiveness of the joint is determined by the reduction in cross-section and/or its deformation caused by the compression.

Performance Requirement

Certain specific requirements with regard to the mechanical and electrical characteristics of the crimped joint have been laid down in different standards which, if fulfilled, can guarantee the satisfactory performance of the joint in service.

Any design of connector or termination forming a joint in service, is expected to meet the following requirements :

(a) the electrical resistance of the joint will remain stable,

(b) the temperature of the joint and the voltage drop across the same will be of the same order as that of the conductor,

(c) the mechanical strength will be adequate (VDE specifies a minimum tensile strength of $4KP/mm^2$),

(d) if the intended use demands, application of short-circuit currents will not cause undue deterioration.

Rigorous tests have been recommended in VDE, draft BSS, draft ISS and UK Electricity council procedures. The salient features are detailed in the following lines:

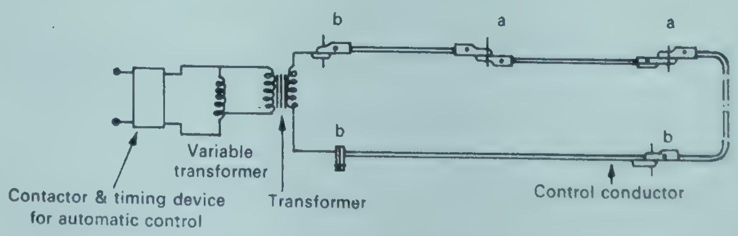


Fig. 2 Terminations—typical test specimen

Test specimens prepared with crimped connectors/ ferrules and lugs are subjected to different tests. The insulation shall be retained on the conductor except as necessary to enable the lug or ferrule to be connected, the potential measuring points to be provided and to enable temperature measuring devices to be placed in contact with the control conductor. Six test specimens are generally to be tested and can be taken from paper insulated or PVC insulated cables, Figures 1 and 2.

(a) Electrical resistance test :— This test is to be carried out initially and thereafter to be repeated on completion of short-circuit test and again to be repeated after electrical load cycling test. The measurement of resistance shall be carried out in reasonably steady temperature conditions, time being allowed for the specimens to acquire

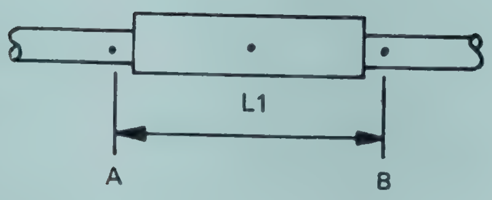


Fig. 3 Through joints

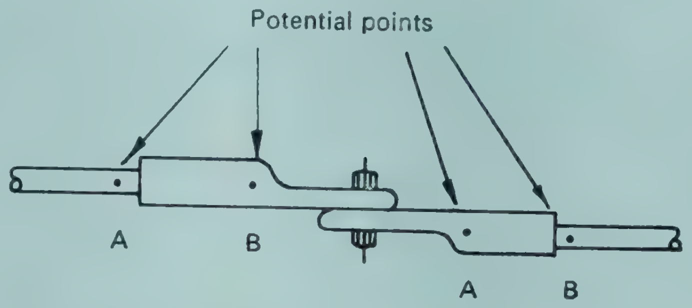


Fig. 4 Terminations

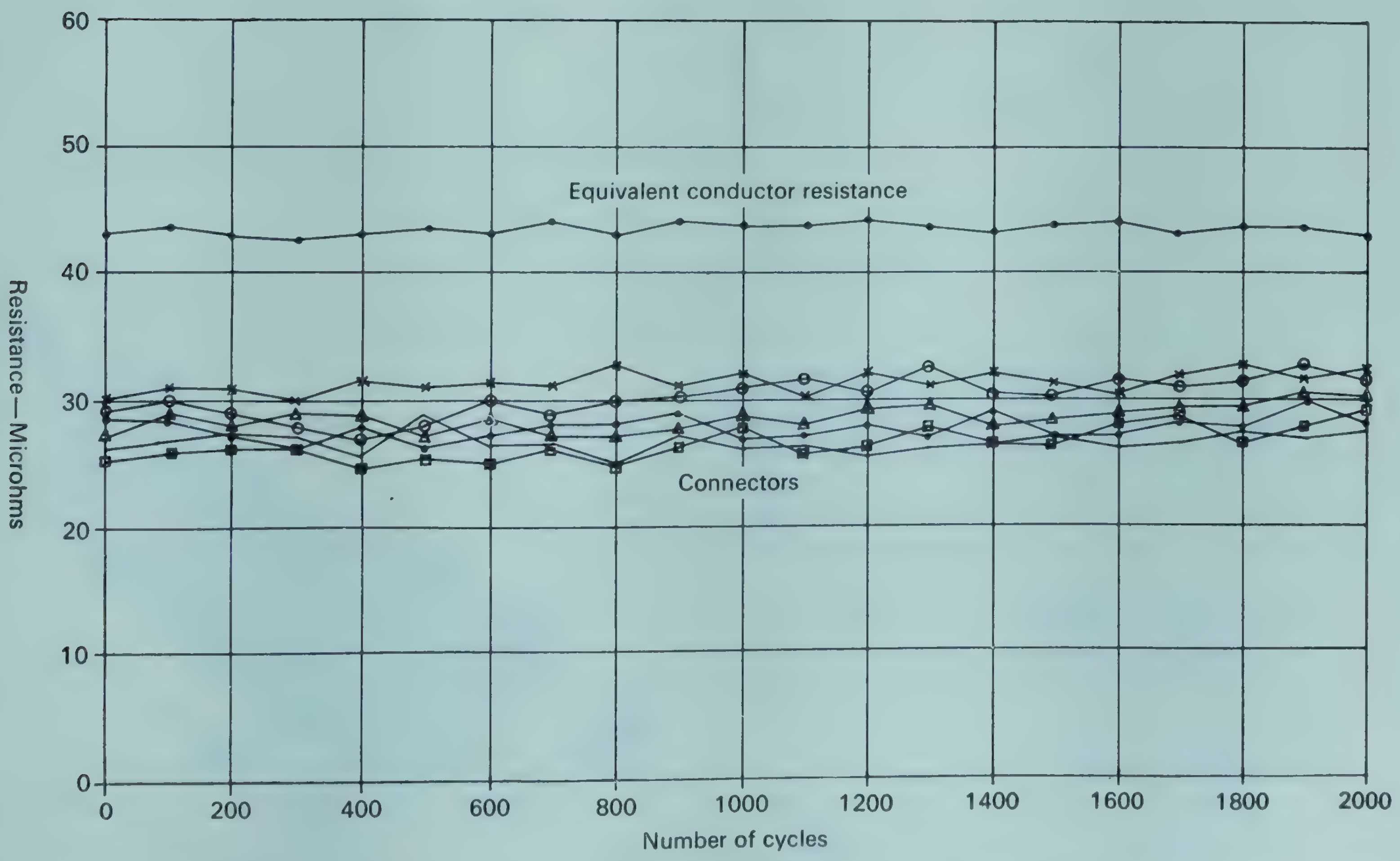


Fig. 5 Variation in electrical resistance of crimped connectors at various intervals during load cycling test

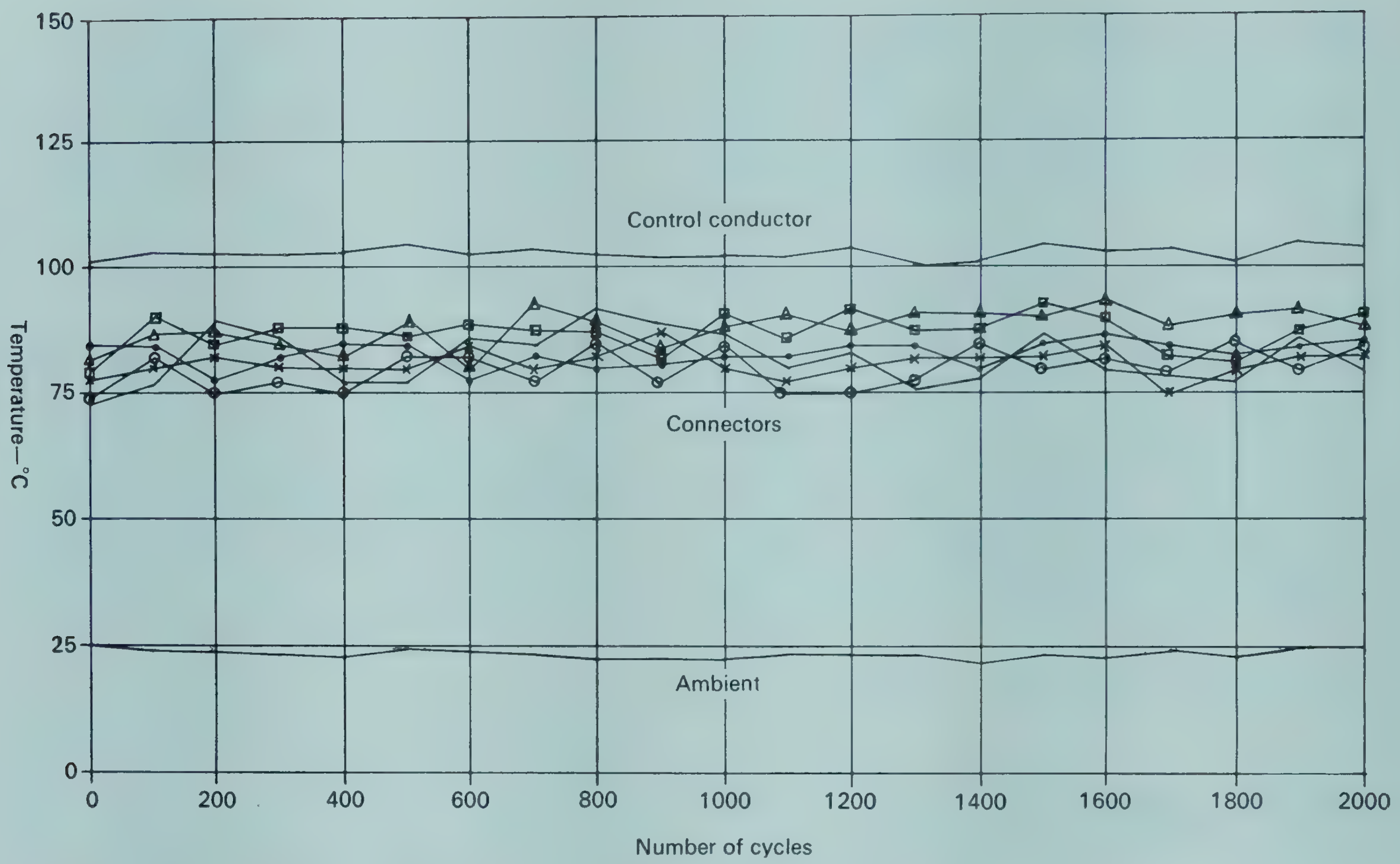


Fig. 6 Comparison of temperature measurement—crimped connection vs control conductor

the surrounding temperature. The resistance of the specimens shall be measured between the potential points as shown in Figures 3 and 4. The instruments used shall be such that measurement can be made to within 1% or 0.5 microhm, whichever is the greater tolerance. The length of time for which samples are allowed to stand/cool before resistance measurements are made, affects the value measured. It is recommended that the successive resistance measurements after short circuit test and/or electrical load cycling tests should be made at least after 12 hours have elapsed.

(b) Short circuit test :— The short circuit current and duration shall be such as to raise the tempe-

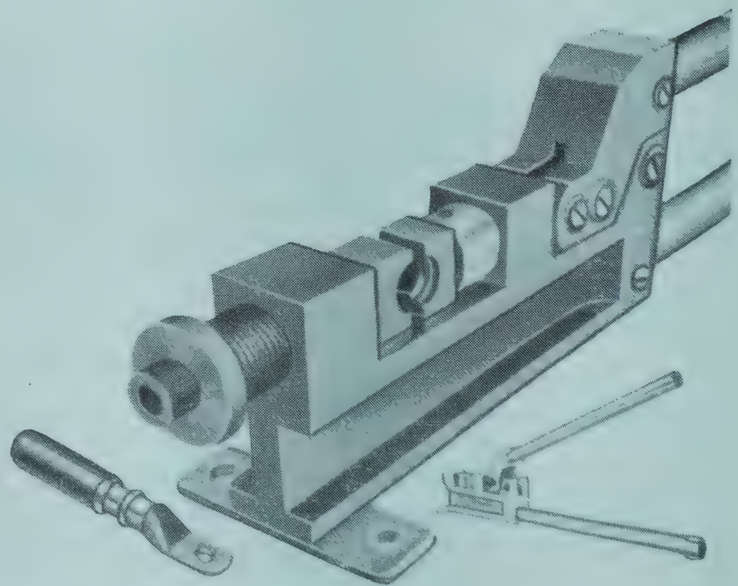
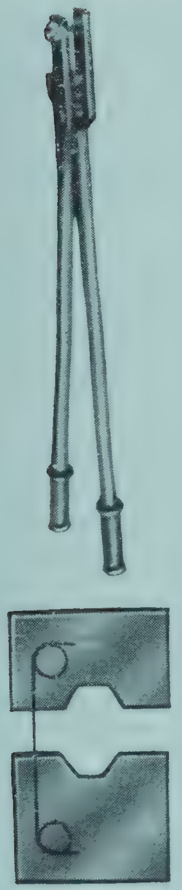
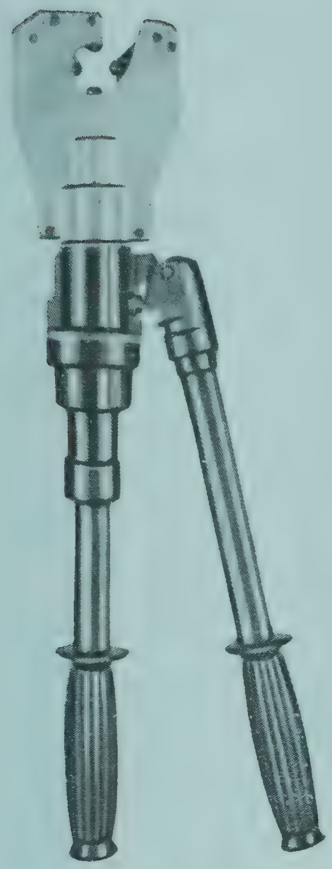


Fig. 7 Hand operated crimping tool





Figs. 8 and 9 Typical hand crimping tools with die set

rature of conductor from ambient to 160°C. Three applications of short-circuit current shall be made, to be followed by electrical resistance measurement. If the resistance measured now is found to be more than 50% or 5 microhms of the initial resistance value, whichever is greater, then the specimens shall be deemed to have failed.

(c) Electrical load cycling test :— Current shall pass for such a time that the temperature of conductor is raised to a minimum of 105°C. This is to be maintained for minimum 5 minutes. At the end of this period the current shall be switched off and conductor allowed to cool naturally to within 5°C of ambient. VDE however recommends the cycle to last minimum 20 minutes total, from switching on of the current till switch-off. Draft IS specifies that at the end of 100 load cycles, the test specimens should be allowed to cool down, and after 12 hours or so, electrical resistance test is repeated. VDE recommends 1000 load cycling, whereas draft BSS and ISS are mentioning 2000 load cycling.

(d) Tensile strength test :— This test shall be carried out on three out of six specimens subjected to above electrical tests. Test specimens shall be inserted in the tensile test apparatus in such a manner as to ensure that the load is applied directly along the axis of the conductor, and the body of the conductor is not gripped by the jaws of the apparatus. The axial pull shall be applied by separating the jaws of the testing apparatus at a steady rate between 25mm/min and 50mm/min.

Availability of Indigenous Tools

A few manufacturers have marketed crimping tools with die/indenture sets and the ferrules/connectors and terminal lugs. Basically these tools are either

(a) portable hand operated (mechanical principle)
(b) portable hand operated (hydraulic principle)
(c) heavier hydraulic tool.

Conductor sizes from 1.5 mm^2 to $1000mm^2$ are covered by the different tools. The die/indenture shapes vary from manufacturer to manufacturer. Figures 7 to 10 illustrate a few available tools and die forms.

Since the IS specification is not yet finalised, it is still left to the manufacturers and the users to satisfy themselves on the performance of the tools and the crimped joints, in line with various test procedures.

Application with Siemens

Siemens have been using crimping technique upto $95mm^2$, and expect to introduce upto $240mm^2$ with hydraulic tool for which tools/die are still under trials.

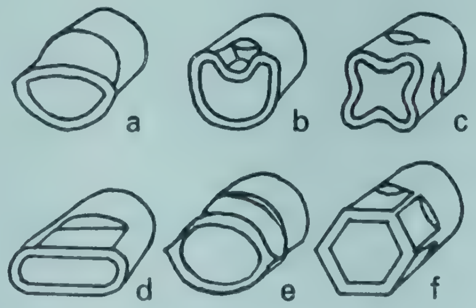


Fig. 10 Double dies used for crimping

High up in a Hanging Cabin

Fig. 1 Hanging cabin

Hanging cabins that glide quietly and exhaust free at 35 kph along an elevated track several metres above the ground, guided by process computers, bringing their passengers to their destinations by the shortest routes—that is the new short distance transportation system developed jointly by Siemens and DÜWAG-Waggonfabrik Uerdingen, and supported by the Federal Department of Research and Technology. After about three years of preparatory work, trials have now begun in the field: On a 180 metre long experimental setup in the Deusseldorf premises of the DÜWAG plant, the various items covered by the project, such as drive, travelling mechanism, track, and above all switches, are tested in interoperation.

The suspension rail was developed as a supplement to the subway and rapid transit systems. It is intended for use in a feeder service for subway and rapid transit routes and for distributing passengers from these trains at their destinations; it is also intended to link satellite towns and suburbs, as well as airports and exhibition centres etc., to the city. Furthermore, it would also be suitable for medium size towns with no subway or rapid transit systems of their own.

The cabins for the suspension rail will be available in different sizes. The present prototype model is the smallest and seats eight passengers comfortably. At peak travelling times another eight standing passengers can be accommodated, while at other times the free space can be used for baby-carriages or wheelchairs, for instance.

Siemens Electrical Equipment for Singapore Water Supply System

The water supply system of Singapore, which has 2.5 million inhabitants, has been extended. Under an order of the city waterworks and the British consultant engineers, Siemens AG has supplied the electrical equipment for a system of pumping stations which are expected to cover the water requirements till approximately 1985. The last one of altogether four pumping stations was recently commissioned. While the daily consumption of approximately 40 million gallons was previously drawn from local sources, i.e. stored and purified precipitation water from the 250 square kilometres of the island of Singapore itself, the additional 60 million now required each day have to be "imported" from Malaysia through a 26 km long pipeline. In the station located on Malaysian territory eight pumps with a total rating of 4100 kW pump the raw water into a reservoir formed by the construction of a dam especially for this purpose; the reservoir is in the outskirts of Singapore in the Pierce district. The raw water line includes 6 pipes with a diameter of 2 m each hung under the 3 km long Causeway bridge connecting the island of Singapore with the mainland. Ten pumps with a total rating of 4400 kW supply drinking water from the 2 purifying stations on the reservoir to the individual districts of the town. The existing station at an old dam also does its bit with 6 pumps rated at 1720 kW. Siemen Germany supplied about three quarters of the electrical equipment for the pumping stations, including the pump drives, cables and wires, lighting equipment together with control and switchgear; the remaining quarter was supplied by Siemens India.

The Centenary of the Crystal Rectifier

In November 1874 Ferdinand Braun, a grammar school teacher in Leipzig, published an article on "Current flow through metallic sulphides." Braun, who later became full professor of experimental physics at Strasbourg University, drew the attention of his fellow scientists to a phenomenon he had discovered while investigating the conductivity of sulphide crystals : the intensity of the current flowing through the crystal depends on the direction of the current. Braun was not able to explain this

departure from Ohm's Law, but he assumed that the rectifying effect was either caused by a gas layer between crystal and wire or was due to the crystal structure itself.

A similar effect was discovered in 1876 by Werner von Siemens while examining the light sensitivity of selenium. He also spoke of the rectifying effect as a "peculiar and contradictory phenomenon" and suspected that the cause lay in an electrolytically influenced boundary layer.

25 years passed before Braun used the crystal rectifier to prove the existence of electromagnetic waves and thus found a replacement for the "coherers." With the development of wireless telegraphy, towards which Braun made a significant contribution with the "Braun transmitter," the crystal detector became more and more important. About 50 years ago the first wireless listeners sat with headphones on in front of the "detector," and fiddled around with the wire contact in an attempt to improve reception by applying it to just the right point on the crystal. The point contact rectifiers were followed by surface contact crystal rectifiers in the 1920s. The latter, which found a wide field of application in ac techniques, replaced the less stable electrolytic rectifiers. The first member of the series of "dry rectifiers" was the copper-oxide rectifier in 1926, the next was the selenium rectifier in 1930.

The principle underlying all crystal rectifiers was a metal semiconductor contact—or so everybody thought at that time—and efforts were made to find a physical explanation of the rectifying phenomenon. The most significant contribution came from Walter Schottky, who published his depletion layer theory in 1939 : as a result of the differing work functions of electrons in a metal and a semiconductor, electrons can travel from the semiconductor to the metal (with suitably selected materials). A carrier-depleted space charge region, which acts as a barrier layer, is created. Depending on the polarity of the applied voltage, this depletion zone either disappears (conduction) or expands (blocking).

Around 1930 the point contact detector had to make way for the electron tube. About 10 years later the point contact diode was once again in favour, because the delay effects inherent in thermionic diodes rule out their employment at very high frequencies, as are customary in radar engineering. The place of natural sulphur crystals was taken by pure germanium and silicon crystals with a certain degree of doping. The Ge and Si point contact diodes were developed around 1940, basically identical diodes are still in use today. Siemens was already producing Ge rectifier elements in Berlin by the end of 1942.

Brattain and Bardeen discovered the transistor effect in 1948. Two point contacts, attached to a Ge crystal for the examination of surface properties, led to the crystal amplifier. Shockley put forward the theory of the pn junction in 1949, which became the principle underlying the pn diode and the transistor. The rectifier mechanism of the metal-semiconductor contact could now be contrasted with that of the pn junction. It was even discovered that selenium rectifiers and germanium point contact diodes formed by a current pulse have pn junctions.

The silicon pn rectifier lent itself ideally to high voltage and current applications. Difficulties however arose in manufacturing pure-state silicon single crystals. In Germany E. Spenke and his team working in Pretzfeld near Erlangen succeeded in developing rectifiers made from pure-state silicon with—initially—an active area of a few mm^2. Nowadays, there are silicon rectifiers with crystal areas of up to 12 cm^2, which can be used at voltages up to 6 kV and currents of over 1000 A. By inserting a weakly conducting zone between the p and n regions, the structure was expanded to obtain pin and psn rectifiers.

Transistor technology advanced in 25 years from the point contact transistor via the alloy transistor to mesa and planar transistors (1960). Silicon planar technology can however be used for metal-semiconductor contacts as well as for pn junctions. The Schottky diode (since about 1963) combines the high frequency advantages of the Si point contact diode with the advantages of the mechanical and electrical stability of the planar semiconductor elements.

The most significant difference between the two types of rectifiers, pn diodes and Schottky diodes, lies in their dynamic behaviour.

Mechanically and Electrically Interlocked Contactor

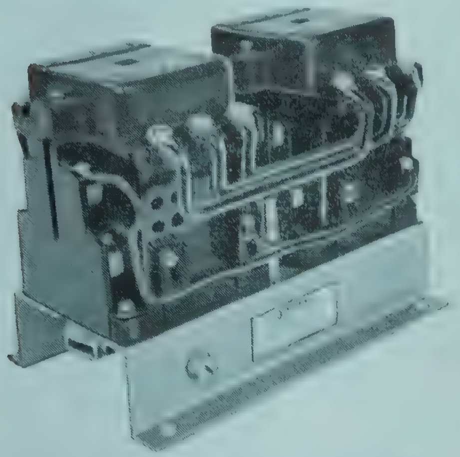


Fig. 1 Siemens contactor type 3TD

In installations, where electrical equipment is subjected to heavy shocks, and vibrations, provision of mere electrical interlocks in reversing starters does not guarantee a safe operation. Sudden shocks could cause both the contactors to close simultaneously resulting in a line-to-line short circuit. For complete dependability and safety in such installations, Siemens have developed a new series of Mechanically and Electrically Interlocked Contactors Type 3TD. These contactors have a wide range of rated current from 16 Amp to 63 Amp. The mechanical interlocking feature is so designed that, simultaneous closing of both the contactors due to heavy vibrations is totally prevented. It also ensures that the two contactors do not close simultaneously even if their coils are accidentally energised at the same time.

These contactors are also provided with the electrical interlocks, which prevent burning out of the coils due to accidental 'ON' command given to a mechanically blocked contactor. All these features are incorporated in extremely compact design, retaining the economy of mounting space.

Siemens S-System Switchboard

In order to provide a compact and economic L.T. Power Control Centre upto 1000A ratings Siemens have now introduced a new sheet steel clad, unitised switchboard system, known as S-System.

The S-System, which provides standard sheet steel prefabricated housings and accessories in ready-to-assemble form, has been specially designed to cater to the requirements of the small scale industrial sector.

Important Features

- The optimised housing dimensions to accommodate switch-fuse feeders and motor control gear in independent housings.
- Ease of assembly and extensibility permit quick deliveries.
- Available in floor mounting or wall mounting type.
- Designed for indoor installations.
- Neat appearance. Two tonne stove enamelled finish.

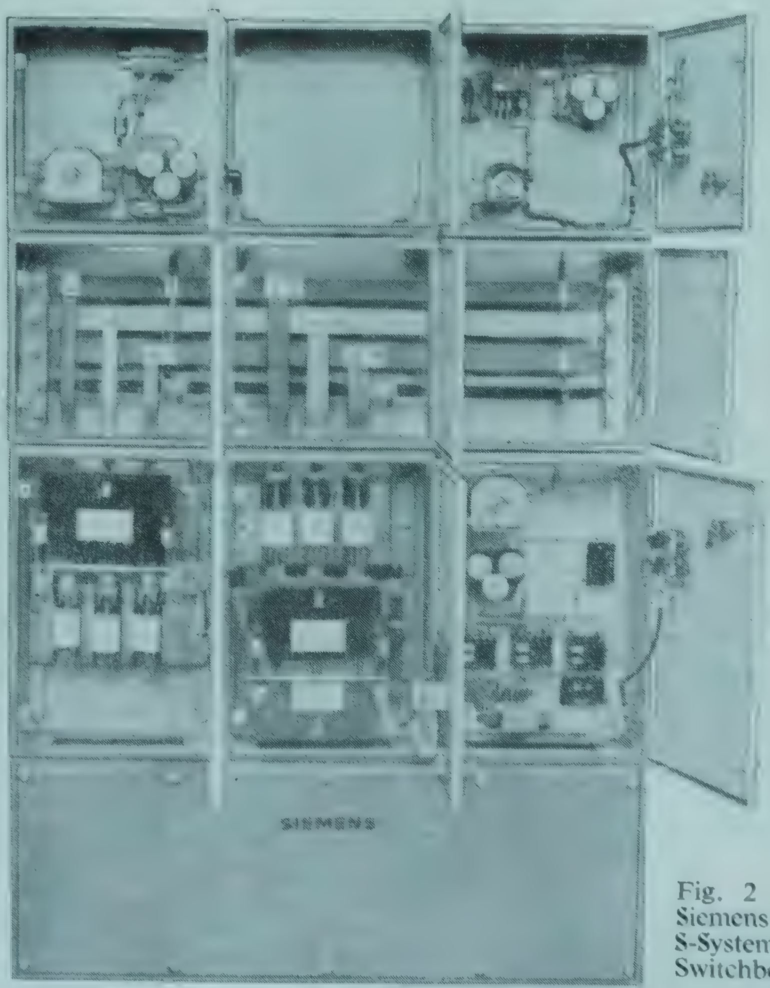


Fig. 2 Siemens S-System Switchboard

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Siemens Circuit

3|75

April 1975

Contents

ESTIMATION OF VALVE OPERATING TORQUES FOR SELECTION OF ELECTRICAL ACTUATORS

—S. V. JOSHI AND S. N. KARMARKAR

For reliable and safe operation of a valve, the selection of an adequately rated electrical actuator is of prime importance. Before selecting an actuator, therefore, it is essential to estimate as accurately as possible the thrust and torque required to actuate the valve under the given operating conditions of flow, pressure and temperature. An adequately rated actuator selected after careful calculations shall deliver at any instant a torque sufficient to overcome the opposing forces. An under rated actuator will fail to respond to the command to close or open a valve thereby causing damage to the plant and equipment resulting in to operational losses and also endangering the safety of the operating personnel. An over rated actuator which will deliver a thrust and a torque far in excess of the requirement, apart from being uneconomical, will result in a damage to the valve itself.

A variety of valves is used in the industry for flow control of fluid flowing through the pipe lines. The methods for estimation of the torques of the following commonly used valves are described in this article.

(i) Screw down Globe/Plug valves.

(ii) Wedge Gate valves.

(iii) Butterfly valves/dampers.

Screw Down Globe Valves

The actuating force (F) required for the positioning of the final control element consists of the following three components :

(a) Frictional Force — F_R

(b) Closing Force — F_S

(c) Static Force in the closed position — F_P

$$\Sigma F = F_R + F_S + F_P$$

(a) Frictional Force — F_R

The force required for overcoming the friction in the valve gland (stuffing box) is estimated under an assumption that the depth of hardening is $< 1\ \mu m$ and that the stuffing box is not packed with more than the required packing :

In case of Carbon (Graphite)/Asbestos packing

$F_R = 1.1 \cdot d + 0.02 \cdot d \cdot \rho'$ kg

where, d = Diameter of the valve stem (mm)

ρ' = Pressure under the stuffing box (kg/cm^2) (against atmospheric pressure)

For the sake of a safer estimation, in the aforesaid equation the pressure in the stuffing box is replaced by the pressure rating 'RP' (kg/cm^2) of the valve.

$F_{RRP} \approx 1.1 \cdot d + 0.02 \cdot d \cdot RP$ kg.

The frictional forces so calculated for different sizes of valve stem diameters and standard rated pressures are listed in Table 1.

Table 1 Frictional force F_{RRP} (kg) for different sizes of valve stem and standard rated pressures.

Rated Pressure RP (kg/cm^2)	Frictional force F_{RRP} (kg) Diameter of the valve stem (mm)					
	16	20	26	32	45	55
16	22.8	28.4	37.6	45.6	64	78
25	25.6	32	42.6	51.2	72	88
40	30.4	38	51	60.8	85.5	105
64	38.1	47.4	64.4	76.2	107	131
100	49.6	62	84.6	99.2	140	171
160	—	86	118	139	194	237
250	—	122	169	195	275	336
320	—	150	207	240	338	413
400	—	182	253	291	410	500

(b) Closing Force — F_S

The force with which the sealing edges of the plug and the valve seat are pressed against each other for obtaining a tight closing of the valve, can be estimated as given here below :

For rated pressure :

$RP \leq 100$ kg/cm^2 : $F_S = 0.75 . Us$ kg

$RP > 100$ kg/cm^2 : $F_S = 0.75 . Us \dfrac{RP}{100}$ kg

Us is the seat circumference in mm

The closing forces F_S estimated as above for different sizes of valve seat and standard rated pressures are listed in Table 2.

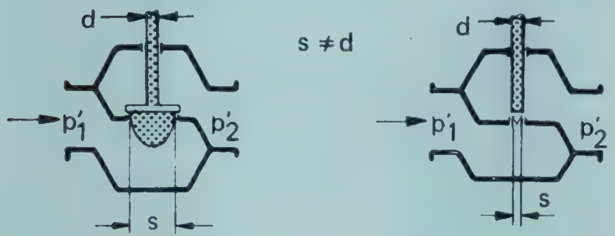
(c) Static and Dynamic Forces—F_P :

The dynamic forces cannot be estimated exactly. Normally therefore, the static forces are determined to which a safety factor is applied. Here it is necessary to differentiate the following operating conditions :

1. The flow helps opening
Basic formula :

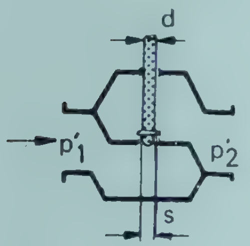
$$Fp = \frac{\pi}{400}\left[P'_1 .\ s^2 - P'_2 .\ (s^2 - d^2)\right]$$
$$= P'_1 .\ A_s - P'_2\ (A_s - A_d)\ \text{kg}$$

s ≠ d



Formula uesd: $Fp = \Delta po \cdot As + p'_2 \cdot Ad$ kg
The resulting force opens.

s = d

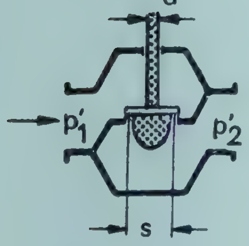


Formula used:
$Fp = p'_1 \cdot As$ kg
The resulting force opens.

2. The flow helps closing
Basic formula :

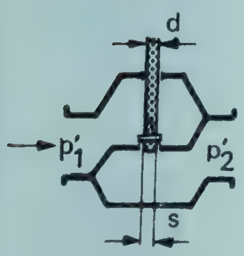
$$Fp = \frac{\pi}{400}\left[P'_1 .\ (s^2 - d^2) - P'_2 .\ s^2\right]$$
$$= P'_1 .\ (A_s - A_d) - P'_2 .\ A_s\ \text{kg}$$

s > d



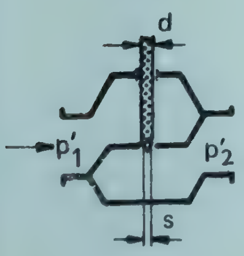
Formula used:
$Fp = \Delta po \cdot As - p'_1 \cdot Ad$ kg
The resulting force opens or closes depending on diameter or pressure relation.

s = d



Formula used:
$Fp = p'_2 \cdot As$ kg
The force opens.

s < d



Formula used:
$Fp = p'_1 \cdot Ad - \Delta po \cdot As$ kg
The resulting force opens.

Table 2 Closing force Fs (kg) for different sizes of Valve Seat and Standard rated pressures.

Seat Diameter s (mm)	Seat Circumfer-ence Us (mm)	Closing Force F_s (kg)			
		Rated 100	Pressure 160	RP 250	(kg/cm2) 320
6	18.85	14.1	22.6	35.3	45.2
8	25.1	18.8	30.2	47.1	60.3
10	31.4	23.6	37.7	58.9	75.4
12	37.7	28.3	45.2	70.7	90.5
15	47.1	35.3	56.5	88.4	113
20	62.8	47.1	75.4	118	151
25	78.5	58.9	94.2	147	188
32	101	75.4	121	188	241
40	126	94.2	151	236	302
50	157	118	188	295	377
60	189	141	226	353	452
80	251.33	188	302	471	603
100	314.16	236	377	589	754
125	392.7	295	471	736	942
150	471.24	353	565	884	1131
200	628.32	471	754	1178	1508
250	785.4	589	942	1473	1885
300	942.48	707	1131	1767	2262
350	1099.6	825	1320	2062	2639
400	1256.6	942	1508	2356	3016
450	1413.7	1060	1696	2651	3393

Ad = Cross sectional area of the valve stem (cm^2), see Table 3

As = Cross sectional area of the valve seat (cm^2), see Table 3

d = Valve stem diameter (mm)

s = Valve seat diameter (mm)

P'_1 = Pressure before the valve (kg/cm^2)

P'_2 = Pressure after the valve (kg/cm^2)

$\triangle P_o$ = Pressure loss across a closed valve (kg/cm^2)

In normal practice, valve stem and valve seats of standard sizes are used. For the sake of ease and to avoid repetition of calculation, the cross sectional areas of the valve seat (As) and valve stem (Ad) as a relation to their diameters are listed in Table 3.

Table 3 Cross sectional area of the valve seat (As) and valve stem (Ad) for different standard sizes.

Diameter (mm)	Cross sectional area (cm^2)	Diameter (mm)	Cross sectional area (cm^2)
6	0.283	75	44.50
8	0.503	80	50.30
10	0.785	85	57.00
12	1.13	90	63.60
15	1.77	100	78.50
16	2.01	125	123
20	3.14	150	177
24	4.55	200	314
25	4.91	250	491
26	5.31	300	707
28	6.45	350	962
30	7.07	400	1257
32	8.04	450	1590
36	10.50	500	1960
38	11.40	600	2830
40	12.60	700	3850
44	15.20	750	4450
45	15.90	800	5030
50	19.60	900	6360
55	23.80	1000	7850
60	28.30	1100	9500
65	33.20	1200	11300
70	38.50		

Wedge Gate Valves

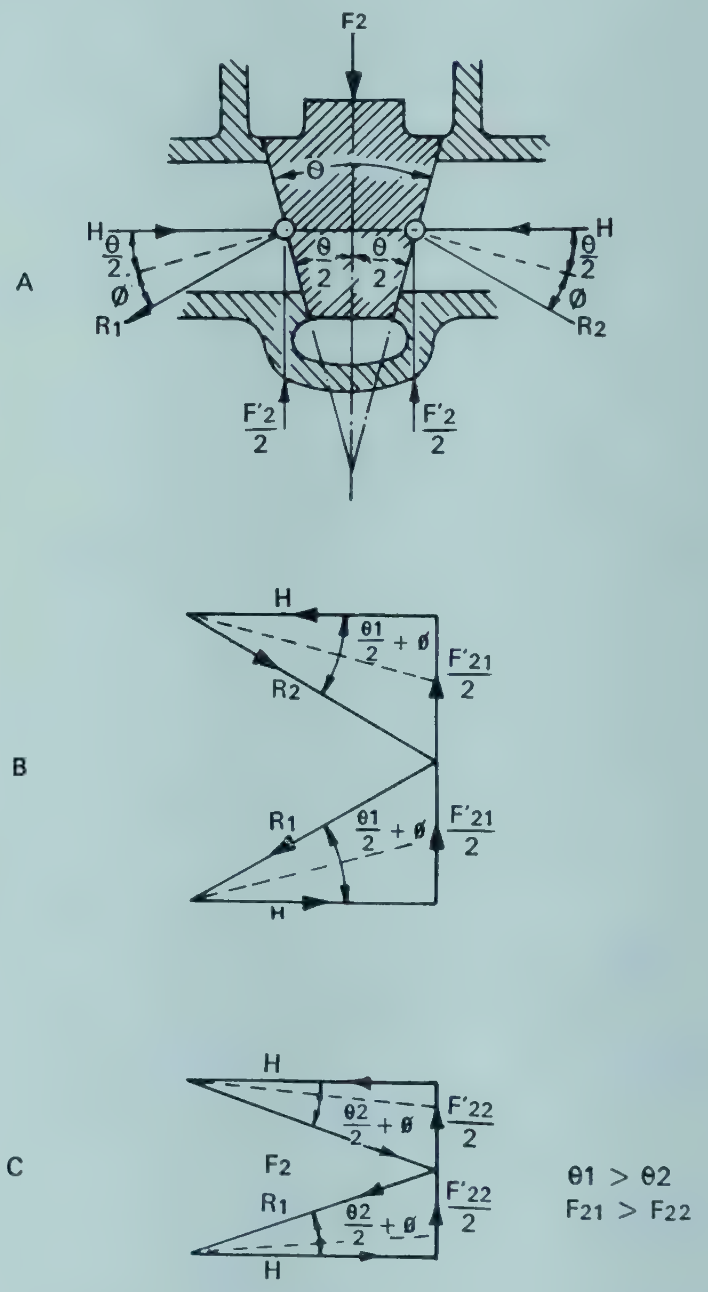
For calculating the torque required for the operation of wedge gate valves, the following forces should be taken into consideration :

(a) F_1 or F_2 — The force due to the differential pressure acting across the valve.

(b) F_3 — The force due to the unbalanced area of that portion of the stem where it passes through the stuffing box.

(c) F_4 — The gland friction allowance.

Additional closing force is not of major importance as the same is achieved by the wedge action of the valve itself.



H Force acting coaxial to the centre line of the pipe line

F2 Force required to overcome the force H

θ Wedge angle of the valve

ø Friction angle

Fig. 1 Force diagrams of wedge gate valves showing increase in required axial force due to increase in the wedge angle

The aforesaid forces can be determined as follows :

(a) $F_1 = A_S \cdot P'_1 \cdot K$ kg

where, A_s = Cross sectional area of the valve seat (cm^2), see Table 3.

P'_1 = Pressure before the valve (kg/cm^2)

K = $\tan\left(\frac{\theta}{2} + \phi\right)$, see Table 4.

θ = Wedge angle of the valve

ϕ = Friction angle ($\mu = 0.2$)

When both the faces of the wedge are in contact with the seat rings, the force required could be twice the value of F_1 particularly in case of small size valves. Therefore,

$F_2 = 2 . As . p'_1 . K$ kg

(b) $F_3 = Ad . p'_1$ kg

where, Ad = Cross sectional area of the valve stem (cm^2), see Table 3.

p'_1 = Pressure before the valve (kg/cm^2)

(c) F_4—the gland friction allowance—should be assumed as 5% of the total of forces F_2 and F_3 calculated as above.

Hence :

$$\Sigma F = F_2 + F_3 + F_4$$

The wedge angle of the valve should diminish with the increase in the size of the valve or else the required axial force becomes enormous. This is illustrated in Figure 1, which shows the force diagram of a wedge gate valve. The typical values of the wedge angle for different sizes of valves and the corresponding values of K, i.e. $\tan\left(\frac{\theta}{2} + \phi\right)$ are listed in Table 4.

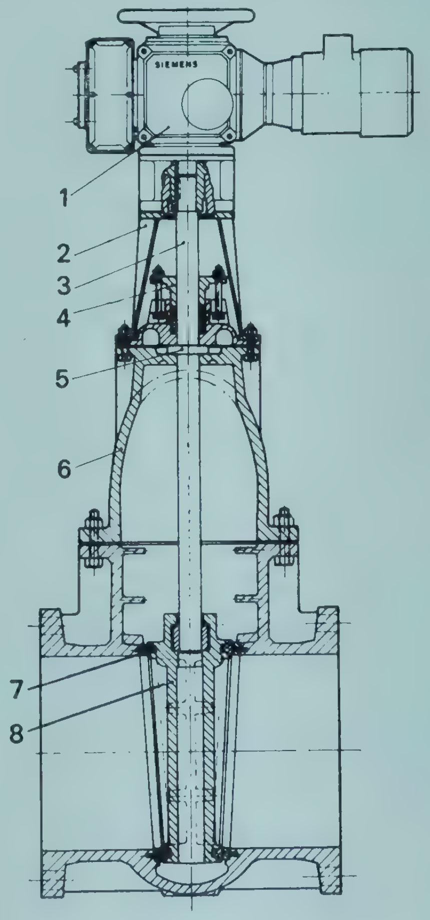
Here the angle of friction ϕ has been assumed to be 11°20′.

Determination of Valve Operating Torques

The required operating torques can be determined on the basis of the total axial force ΣF estimated as above for the screw down globle valves and wedge gate valves.

Table 4 Typical values of the wedge angle for different sizes of valves and the corresponding values of K, i.e. Tan $(Q + \phi)$.

Valve size in mm	Wedge angle θ	$K=\tan\frac{(\theta+\phi)}{2}$	Valve size in mm	Wedge angle θ	$K=\tan\frac{(\theta+\phi)}{2}$
50	10°	0.294	400	$6\frac{1}{2}$°	0.260
65	10°	0.294	450	$6\frac{1}{2}$°	0.260
80	10°	0.294	500	6°	0.256
100	10°	0.294	600	$5\frac{3}{4}$°	0.254
125	9°	0.284	700	$5\frac{3}{4}$°	0.254
150	9°	0.284	750	$5\frac{3}{4}$°	0.254
200	8°	0.274	800	$5\frac{3}{4}$°	0.254
250	8°	0.274	900	$5\frac{1}{4}$°	0.250
300	$7\frac{1}{2}$°	0.264	1000	$5\frac{1}{4}$°	0.250
350	$7\frac{1}{2}$°	0.264	1100	5°	0.246
			1200	5°	0.246



1 Actuator
2 Mounting stool
3 Valve stem
4 Stuffing box and Gland
5 Thrust collar
6 Valve body
7 Valve seat
8 Wedge gate

Fig. 2 Cross-sectional view of a wedge gate valve with Siemens electrical actuatoı type ANED

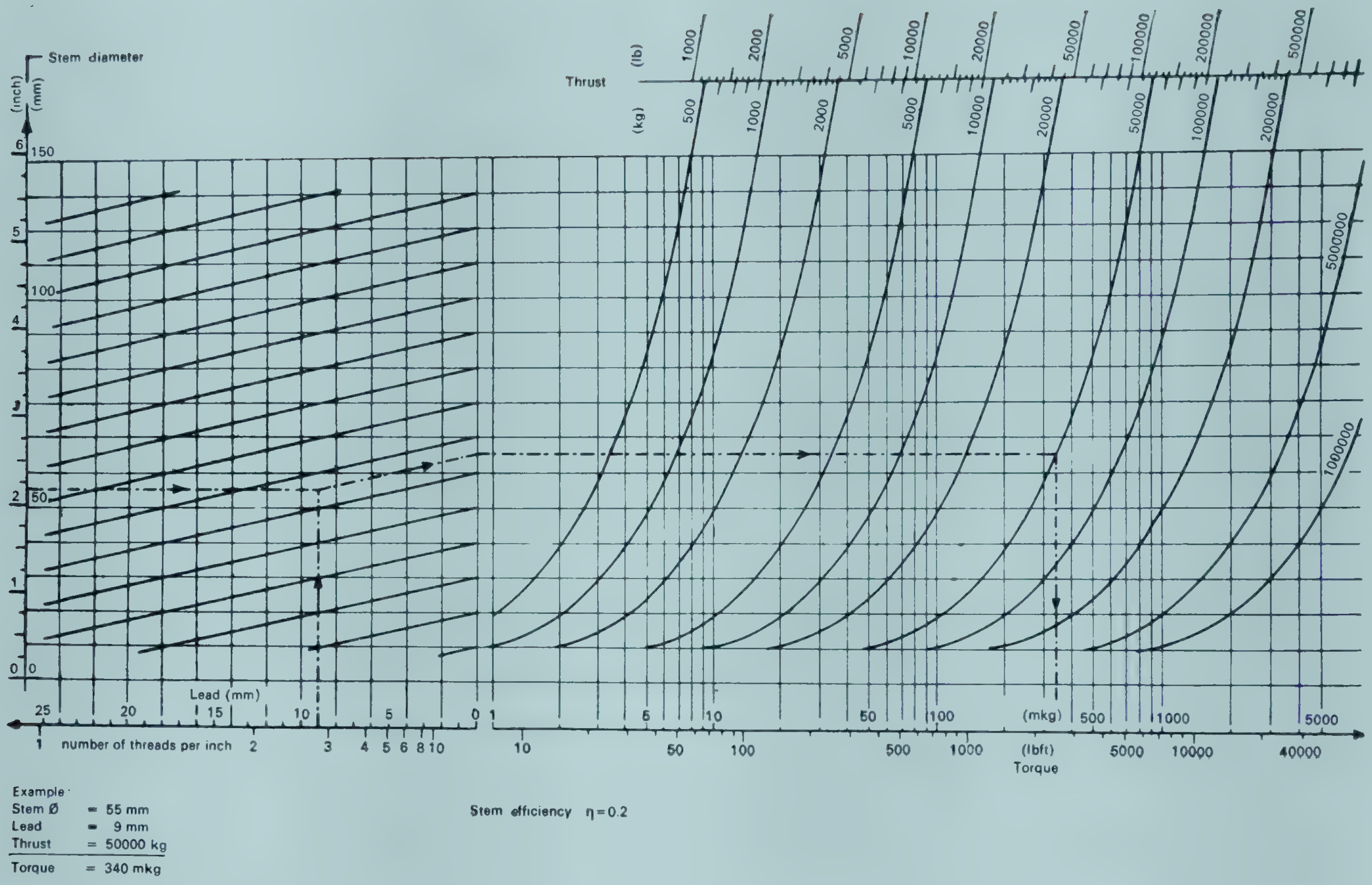


Fig. 3 Torque determination for different final control element data

The output torque of the selected actuator should be adequate to overcome the torque T_A due to the total axial force ΣF and torque T_B due to the frictional resistance to the rotation of the stem collar. The torques T_A and T_B can be estimated as herebelow :

(a) $T_A = \Sigma F \cdot \frac{dm}{2000} \cdot \tan(\alpha + \phi_t)$ mkg

where, T_A = Torque in mkg
F = Total force in kg
dm = mean thread diameter in mm
α = Angle of threads
ϕ_t = Angle of friction of the threads.

However, the torque T_A can also be quickly and easily determined by using the graphical method illustrated in Figure 3 and explained by means of an example considering assumed values of Stem diameter, lead and thrust (ΣF).

(b) $T_B = \Sigma F \cdot \frac{dc}{2000} \cdot \mu c$ mkg

where, T_B = Torque in mkg
ΣF = Total force in kg
dc = mean collar diameter in mm
μc = Coefficient of friction between collar and body.

Butterfly Valves/Dampers

The torque requirements for the operation of a butterfly valve vary substantially with the differential pressure across the valve and the fluid velocity. Further, the torque requirement varies with the type of the valve and its design considerations. However, the following method shall serve to approximately estimate the torque requirements.

In case of butterfly valves the angular rotation of the valve disc varies the area of opening, thus causing a change in the rate of flow. For this, certain torques, which operate on the valve disc, have to be overcome. Just as in the case of valves, these can be differentiated as herebelow :

Frictional torque M_R through valve glands (stuffing box) and bearings;

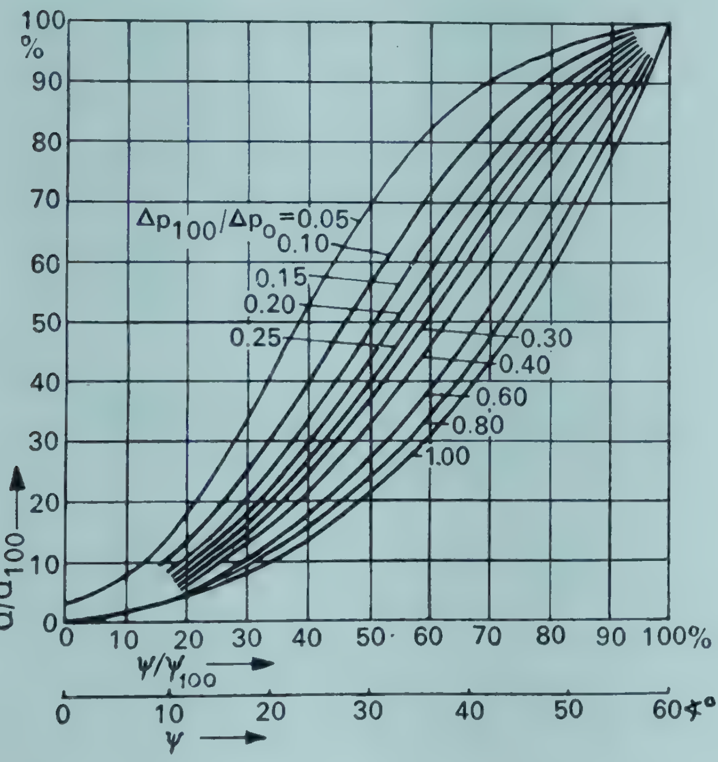
Closing torque M_S, for rotating the disc to the close position where angle of opening $\psi = 0$;

Static and dynamic torques M_P resulting due to the pressure loss $P'_1 - P'_2$.

Torques M_R and M_S appear only when the valve disc is rotated whereas torque M_P is effective even in the standstill condition of the valve.

The positioning torque M_A of the actuator should be larger than the sum of the maximum possible torques throughout the range of the valve rotation.

$$M_A \geqq \Sigma M = M_R + M_S + M_P$$



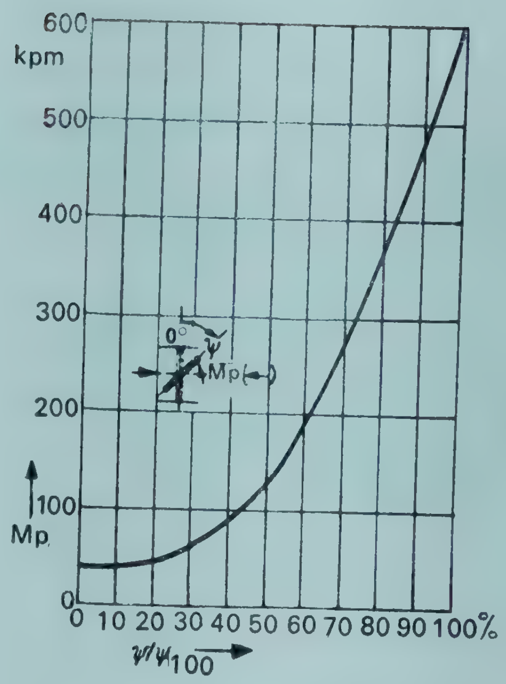
Q Rate of flow

ψ Angle of opening

Δp Pressure drop across the valve

D Diameter of butterfly valve

Fig. 4 Characteristic curves of Butterfly valves



Q Rate of flow

ψ Angle of opening

Δp Pressure drop across the valve

D Diameter of butterfly valve

Fig. 5 Dynamic torque Mp of a Butterfly valve 1m ϕ valve disc. ψ 100=60

Frictional Torque

The frictional torques on butterfly valves when in operation are difficult to assess. As in the case of valves here also one has to differentiate between gland (stuffing box) friction and bearing friction. As against the valves, where the friction in the guides can be neglected, in butterfly valves an additional loading of the bearings occurs which is dependent on Δp and the diameter of the valve disc. Due to the bending of the shaft, this additional load can be quite substantial even in the case of externally located bearings. In comparison, the load dependence of the stuffing box is negligible in the lower pressure ranges. An approximate estimation of the frictional torque is possible by the following equation :

$$M_R = \left(\frac{d}{10}\right)^2 + 0.4\left(\frac{D}{100}\right)^2 \cdot \Delta p \qquad \text{mkg}$$

d = shaft diameter in mm

D = Valve size in mm

Δp = Pressure loss in Kg/cm^2

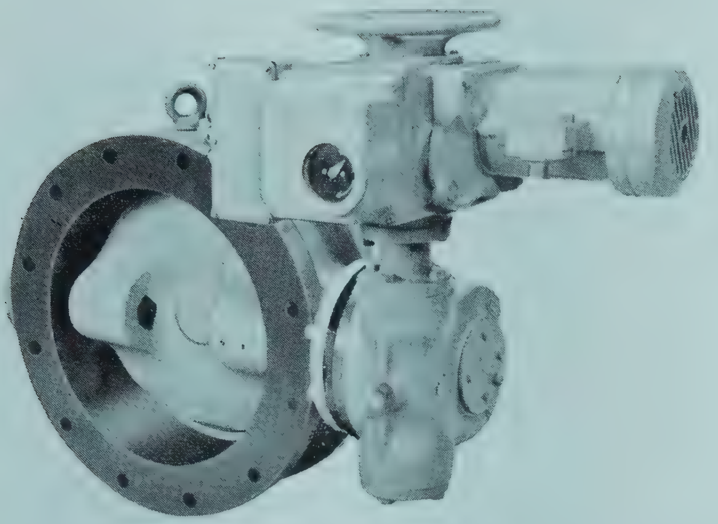


Fig. 6 Siemens electrical actuator series AN with Intermediate Worm Gear mounted on a Butterfly valve.

Closing Torque

Here it is essential to differentiate between a ‘Turn-through’ and ‘Striking vane’ type Butterfly valves. While a closing torque does not appear in the case of a turn-through butterfly valve in its brand new condition, it is required for the tight closing of a striking vane type butterfly valve. It should, however, be mentioned that a too conservatively calculated actuator is not able to close the valve disc when it is prevented from closing by deposits of suspended impurities and dirt. With sufficient torque reserve in the actuator, the turn-through butterfly valve acquires the property of self-cleaning at the closing position.

Static and Dynamic Torque

In case of absolutely symmetrically mounted shafts through the centre of the valve, no torques appear in the closed position of the valve. With increasing angle of opening φ, the dynamic torque increases upto 80° and then subsequently falls steeply to zero at 90°.

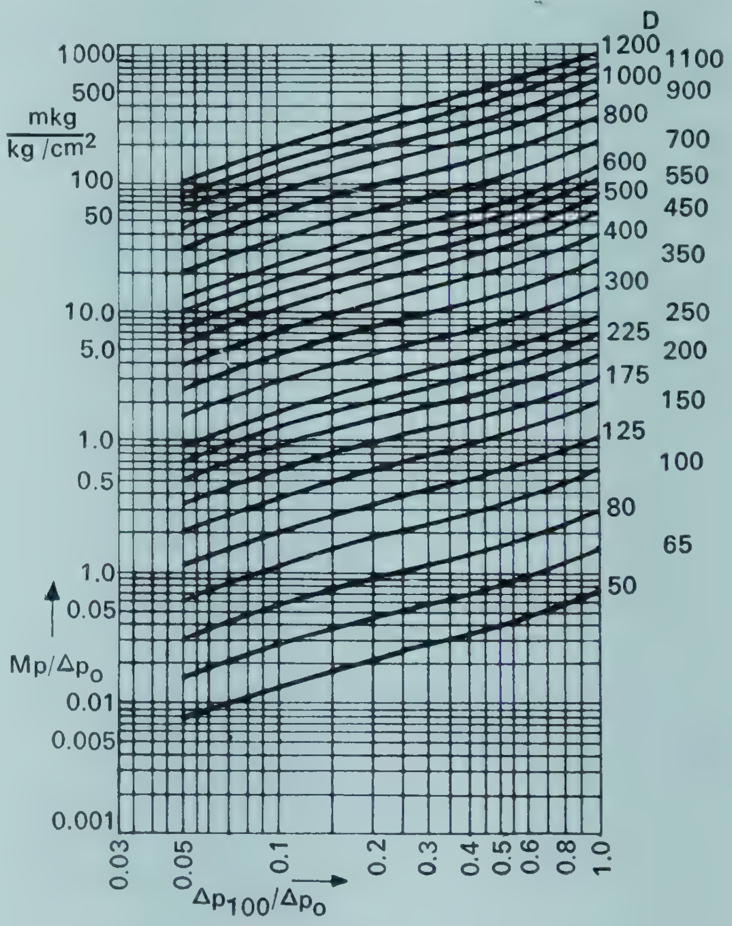
Figure 5 shows the dynamic torque curve of a 90° rotation butterfly valve having a disc of 1 metre diameter and a constant pressure loss of 1 kg/cm². If, however, the behaviour of the valve is considered for varying pressure loss, Figure 4, then the maximum torques appearing in the range of the angle of opening between 0 to 60° can be represented as a function of $\triangle p_0$ and plotted against $\frac{\triangle p_{100}}{\triangle p_0}$ as shown in Figure 7.

The actual torque Mp can be determined by multiplying the ascertained value of $\frac{Mp}{\triangle p_0}$ by $\triangle p_0$

Here

$\triangle p_{100}$ = Pressure drop across the valve at flow Q = 100% for which the valve is designed, (Q_{100} is the flow that occurs at 60% opening of the valve)

$\triangle p_0$ = pressure drop across the valve in the closed position of the valve.



Q Rate of flow

Ψ Angle of opening

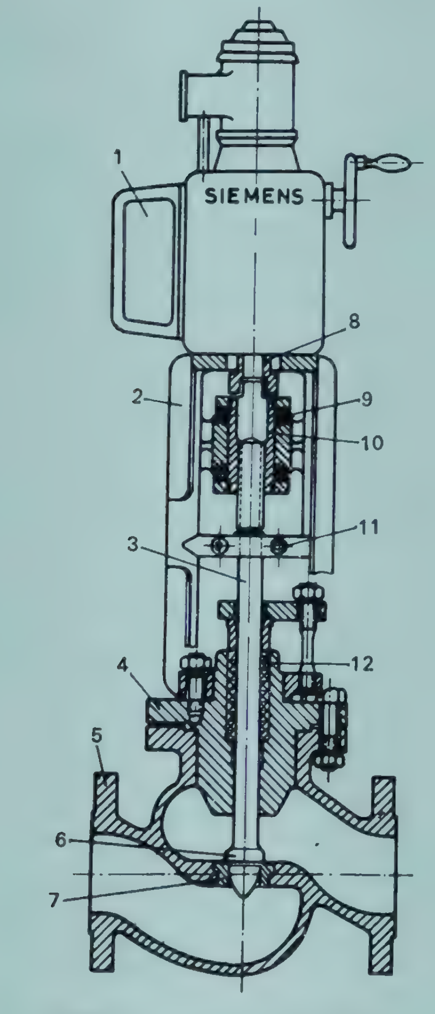
Δp Pressure drop across the valve

D Diameter of butterfly valve

Fig. 7 Dynamic torque Mp as a function of Δpo and Δp100

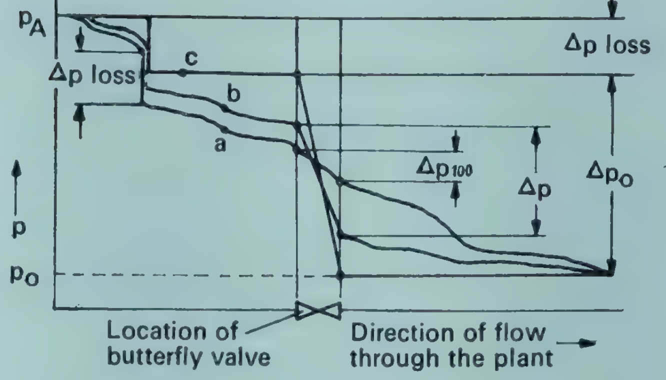
Thus, for the determination of the torque required for the operation of the butterfly valve it is essential to know the valve design details with respect to pressure p_1 and p_2 before and after the valve at 100% flow, pressure drop $\triangle p_0$ in the closed position of the valve, diameters of the valve disc and the valve shaft.

The American Water Works Association (AWWA) have issued a Standard Ref. AWWA C504-74 for rubber seated butterfly valves for water services. Table 1 on page 2 of the edition approved on June 21, 1974 which details the maximum operating torques for different sizes of butterfly valves depending on the pressure class and velocity, is reproduced in Table 5.



1 Actuator
2 Yoke
3 Valve stem
4 Cover
5 Body
6 Plug
7 Valve seat
8 Coupling element
9 Axial ball bearing
10 Rotating threaded bush
11 Position indicator
12 Stuffing box packing

Fig. 8 Electrical actuator type KE6 mounted on a valve



a at Q 100 (valve completely open)
b at Q mid (valve in the middle position)
c at Q ≈ 0 (valve closed)

Q Rate of flow
Ψ Angle of opening
Δp Pressure drop across the valve
D Diameter of butterfly valve

Fig. 9 Pressure change in a pipe line

Tab. 5 Maximum operating torques* as per AWWA for different sizes of butterfly valves depending on the pressure class and velocity.

Valve Diameter in.	Maximum Torque—ft-lb.					
	Class 25A†	Class 25B†	Class 75A†	Class 75B†	Class 150A†	Class 150B†
3	8	8	12	12	19	19
4	14	14	22	22	36	36
6	33	33	52	52	93	93
8	61	63	95	95	175	175
10	98	115	160	165	320	320
12	146	200	240	280	510	510
14	205	310	340	450	720	720
16	275	470	470	670	1,030	1,030
18	360	660	600	940	1,350	1,480
20	445	920	770	1,300	1,800	2,050
24	680	1,550	1,200	2,200	2,900	3,500
30	1,250	3,100	2,100	4,350	5,300	6,750
36	2,150	5,400	3,400	7,550	8,500	11,600
42	3,400	8,450	5,350	12,000	12,800	18,400
48	5,050	12,700	8,000	18,000	18,500	27,500
54	7,250	17,000	12,000	25,500	29,500	40,000
60	9,900	24,800	16,100	35,000	38,500	54,000
66	13,300	33,000	21,400	46,000	49,500	71,000
72	17,000	42,500	27,000	60,000	60,500	90,000

* Torques represent maximum capability for which valves are to be applied.

† In each case, numerical class designation is the maximum nonshock shutoff pressure, in lbs./in².
NOTE: 1 mkg. = 0.138 ft-lb.

—R. NATH

In the first part of this article, we discussed the Refrigeration System, the power circuit and the controls on board ships. In this article, the special features required for the motor for the cargo refrigeration plant are given.

Motors

All motors used for the cargo refrigeration plant i.e. for compressors, pumps, diffuser fans etc, must comply strictly with the specifications of the classification societies like Lloyds Register of Shipping etc. Some of the salient features to be borne in mind while selecting the motors are given below.

(a) Temperature rise/Insulation Class

The life of a motor is equal to the life of its winding insulation; the wear of the bearings and other mechanical parts, can be replaced at a comparatively low cost and are therefore not quite as important. Any service conditions influencing the temperature rise and thus the condition of the insulation should therefore be given particular attention.

The temperature rise in degree centigrade can be expressed as :

$$TR = \frac{V}{Wa}$$

TR — temperature rise in deg. centigrade

V — losses in W.

Wa — Heat, dissipating capacity in W/deg.

The losses V can be determined from the formula

$$V = P—N$$

$$V = \frac{(100—\eta)}{100} \times P = \frac{100—\eta}{\eta} \times N$$

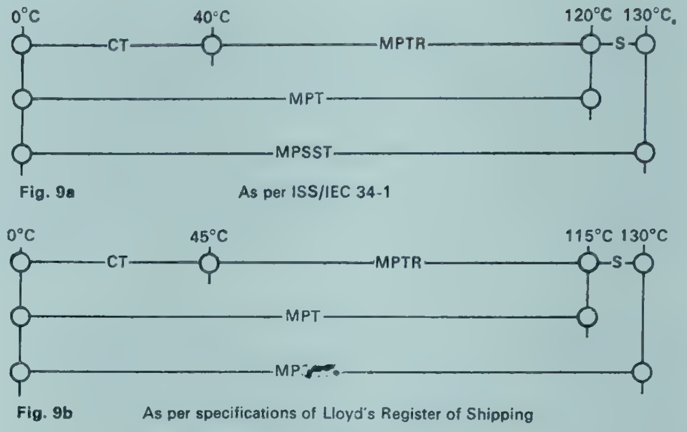
V = total losses in kW

N = Mechanical power delivered by motors shaft in kW (power output)

P = Power drawn from the system in kW (power input)

η = efficiency in %

Wa is the heat dissipating capacity which is dependent on the size of the motor surface, ventilation conditions and the ambient temperature.



CT Cooling medium temperature: 40 deg. C (45°C)
MPTR Maximum permissible temperature rise: 80 deg. (70°C)
MPT Maximum permissible temperature: 120 deg. C (115°C)
S Safety allowance: 10 deg. (15°C)
MPSST Maximum permissible steady-state temperature: 130 deg. C (130°C)

Note: Figures in brackets are permissible values as per specifications of Lloyd's Register of Shipping

Fig. 9 Permissible temperature rises in motors with 'B' class insulation

Under normal operating conditions, motors are designed to ensure a minimum service life of 20-25 years. However, as the winding temperature increases beyond its limiting values, the life of the winding insulation and hence that of the motor reduces considerably—as a thumb rule, by about half the time for each 10°C. It is therefore essential that the limiting values specified for the particular material must be strictly adhered to—see Table I.

Table 1

Analysis of temperature rises for windings of motors upto 1000V.

	IEC 34-1/IS			Lloyds Register of Shipping		
Insulation class	A	E	B	A	E	B
Ambient	40	40	40	45	45	45
Temp. rise (by thermometer) method	50	65	70	40	55	60
Temp. rise (by resistance method)	60	75	80	50	65	70
End temperature (by resistance method)	100	115	120	95	110	115
To get hot spot approx. ..	10	10	10	10	10	10

From the above table, it can be seen that the maximum permissible steady state temperature for an insulating material is made up of the cooling medium temperature, the maximum permissible temperature rise and a safety allowance (to account for hot spots). Figure 9a illustrates this for a 'B'

class insulation at 40° C ambient and Figure 9b illustrates the same as per limits specified by M/s. Lloyds Register of Shipping. From Figure 9b, it is apparent that the specifications of M/s. Lloyds Register of Shipping considers:

i. a higher ambient temperature (45° C).

ii. a higher factor of safety for hot spots.

(b) Enclosure

Motors in drip proof enclosure (IP 23) could be used in under deck locations where hosing down is not required viz. compressor motors. On the other hand motors should be in TEFC hose proof enclosure (IP 55) with bearing oil seals and specially sealed joints in case their place of installation requires hosing down operations.

(c) Other Requirements

The motors should be coated with a special acid/alkali resistant paint to ward off corrosion. The motor shaft material should be EN8 grade steel. The motors should be provided with water tight brass glands.

Compressor Motor

Figure 10 depicts a motor driving a multi-cylinder two stage compressor. This unit is generally mounted parallel to the longitudinal axis of the ship in order to limit the gyroscopic forces on the bearings.

A typical torque/speed curve of a compressor is shown in Figure 11. The compressor starts unloaded for a duration of 45 secs. and after this period the load comes on.

(i) Choice of Driving Motor

When choosing the electric motor, the magnitude of the starting torque Ma should be considered. When the compressor starts unloaded, the following torques occur.

Mr = pull out torque, for actuating the compressor (constant)

Mw = friction torque (constant)

Mi = resistance torque (variable)

Mc = additional torque (only in compound compressor)

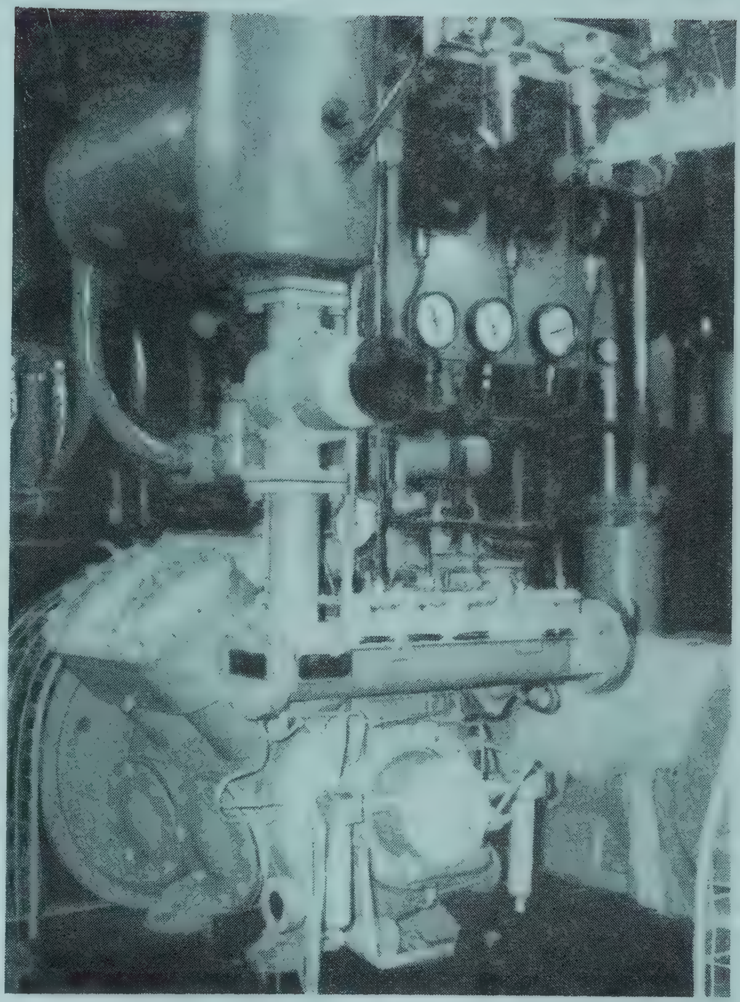


Fig. 10 Compressor motor (75/60 hp. 4/6 pole) installed on Board Ship VC 171 of Hindustan Shipyard Ltd.

For single stage compressor apply:

$$Mi = Z.A.\ P_o$$

For compound compressors apply:

$$Mi = (Z_{LP}.\ A_{LP}.\ P_o) + (Z_{HP}.\ A_{HP}.\ P_m) \text{ and}$$

$$M_c = B(P_m - P_o)$$

z = total number of cylinder.

Z_{LP} = number of LP cylinder.

Z_{HP} = number of HP cylinder.

P_o = suction pressure during compressor starting (bar).

P_m = Interstage pressure during compressor starting (bar).

A = factor dependent on compressor speed, cylinder bore, refrigerant.

B = factor dependent on type of compressor.

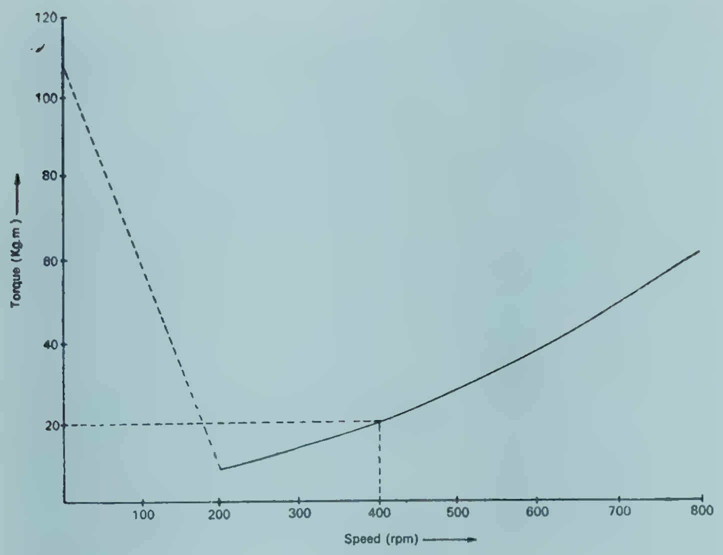


Fig. 11 Torque/speed characteristics of a compressor

In order to actuate the compressor from its position of standstill and to accelerate it upto operating speed, the total starting torque required is:

Type of Compressor	For actuating component	For accelerating component upto the operating speed
Single stage ..	$Ma=M_r$	$Ma=M_w+M_i$
Compound ..	$Ma=M_r+M_c$	$Ma=M_w+M_i$

The load torque characteristics of the compressor is thus found. It is now necessary to find a suitable motor considering the above starting torque and the accelerating torques.

(ii) The Motor Torques

The torque delivered by the shaft of a 3-phase induction motor varies greatly between zero speed and synchronous speed, see Figure 12. The range between $M=0$ and $M=Mn$ is the working range, $M=M_a$ to $M=M_k$ covering the acceleration range. As per IS specifications, the allowable tolerances for the starting torque and the breakdown torque are $\pm$ 20% and $\pm$ 10% respectively. Hence allowing for these tolerances, the starting torque must exceed the breakaway torque of the driven machine by a sufficiently large amount, and the motor torque during the run-up to working speed must always be higher than the load torque.

On the other hand, the acceleration torque should remain within limits, since otherwise the mechanical transmission elements and the driven machine may sustain damage.

The pump and the diffuser fan motors are to be selected on the above basis. In case of the diffuser fan motors (which are located in the refrigerated hold) special bearing lubrication should be provided suitable for temperatures as low as —30 °C.

Conclusion

With advance in refrigeration technology, cargo ships with larger refrigerated holds are being built (7300 m^3 useful refrigerated cargo capacity at —24° C). The ships being built at Hindustan Shipyard Ltd, have a refrigerated cargo capacity approx. of 1100 m^3 at —23° C.

However it would not be out of place to mention that with the advent of containerisation in the transport of cargo, refrigerated containers (capacities from 2 to 35 m^3 and size usually 8′×8′ and 20′ long) are finding wide use. These containers have two separate refrigerating systems, using refrigerant R12 the compressors being driven by universal motors, with air condensers and natural circulation evaporators. The containers are usually carried as deck cargo and are hooked up to the ships' supply system. Alternatively these containers may have only fans which draw chilled air from a common portable refrigerating unit supplying to a row of such containers.

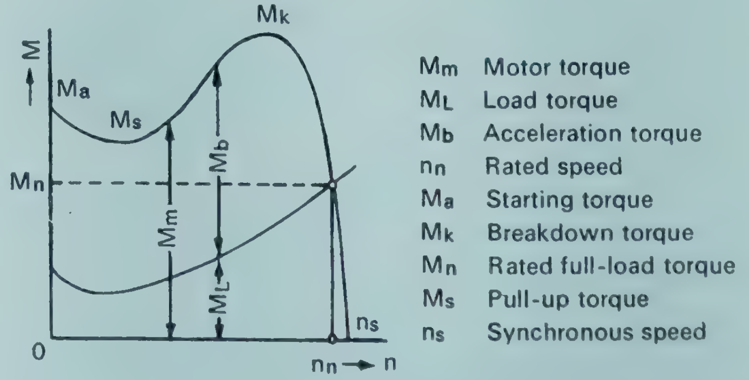


Fig. 12 Torque/speed characteristics of a Squirrel Cage motor

—S. N. GHOSH

Introduction

Electric motors play a vital role in various industrial applications. It would be improper to choose a motor merely on the basis of its output-rating and speed. There are many other factors, such as supply voltage, frequency, environmental condition, dutycycle, type of protection etc., which are equally important for the operation of the correct type of motor for a particular type of duty.

The commonest form of electric motor is the cage type induction motor, which is used for many applications. This is on account of its simplicity in operation, robust construction and low cost. However, this motor has an inherent drawback due to its high starting current/torque ratio. This has resulted in the use of different types of starting equipment to reduce the high starting currents and thus limit their effect on the supply networks.

With the progress of time, the developments and latest design techniques have made it possible to overcome these difficulties to a great extent. Relatively minor modifications to the rotor designs (namely, deepbar, sash-bar or double cage rotors) enable motors to be offered, with a significantly better starting performance, than the ordinary cage motor.

With the different rotor designs various kinds of starting performances have been achieved. In the present article a broad spectrum of various starting characteristics, namely starting current and torque relationship, under different rotor constructions have been reviewed.

Starting Characteristics According to NEMA

The National Electrical Manufacturer's Association (USA) have laid down certain basic recommendations on the employment of electric motors. These are essential for the application. of the different rotor designs for which they are intended.

NEMA have standardised the performance characteristics for various sizes and types of motors including starting current, starting and breakdown torques (pull out torque), slip and locked rotor kVA.

These standards afford immense help to the designer/ manufacturers as well as the consumers, who have anything to do with the motor.

NEMA have recommended five basic designs of

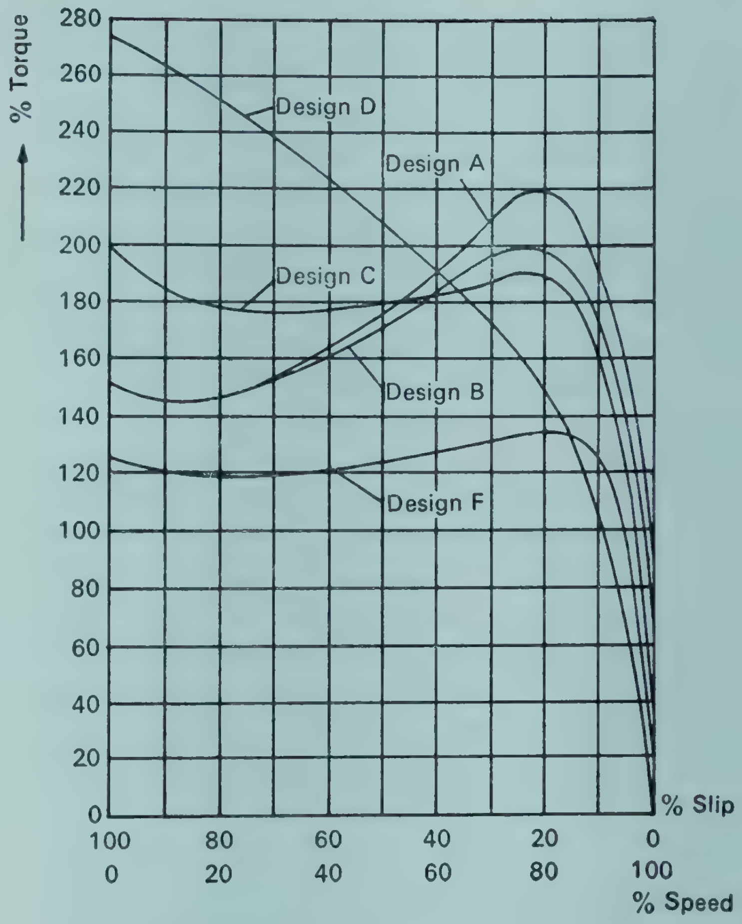


Fig. 1 Speed-torque characteristics of motors for various designs as per NEMA

three-phase Squirrel Cage motors. Each design provides a various combination of torque, current and speed characteristics to fulfil the technological requirements of different industrial applications. Any related problem with respect to output inrush current and other inter alia parameter can be solved with one of the five designs.

These designs are classified as follows :

Design A

Motors with normal starting torque, normal starting current and low slip.

The design of motor is similar to a general purpose motor, which is mainly used to drive the machine with relative inertia loads. The motors are designed for smaller loads under direct-on-starting at rated voltage. The motor has high pull-out torque, high locked rotor current and a low slip at full load.

Design B

Motors with normal starting torque, low starting current and low slip.

The Design B motor is used for a wide variety of industrial applications, such as blowers, ventilators, pumps, lathes, grinders and certain other machine tools. Normally the motor will have sufficient torque to accelerate against the full load torque. In other words, the starting torque of the motor is slightly higher than the rated torque. The starting current is limited to relatively low value to meet the requirement of the supply system, due to the application of various types of machines. The slip is kept to a low value, which is less than 5%.

Design C

Motors with a high starting torque, low starting current and low slip.

The Design C motor is similar to that of Design B motor except for the torque requirement. The motor will produce high starting torque under direct-on-line starting (at full voltage) to meet the requirement of the machines. However, the starting current is restricted to its specified limit. This design does not cater for the high overload demand after the attainment of full load speed.

The Design C motors are generally employed for the compressors, pulverizers, conveyors, stairways and similar equipment. The slip of the motor is practically the same as that of motor of Design B.

Design D

Motors with high starting torque, low starting current and high slip.

The Design D motor develops high starting torque under full voltage starting and the starting current is limited to a comparatively low value. When a sudden surge load is applied, the speed of the motor decreases initially, but the motor develops high torque to recover the speed rapidly. This motor has no well defined pull-out torque.

The Design D motors are normally used for machines with sudden and frequent heavy loads. Typical applications of machines, like crane and hoist, centrifuge, elevators, punch presses and machines with large flywheels.

These loads may be of continuous or may be of intermittent duty. The Design 'D' motors have to be made depending on the type of duty. In fact, there are two different types for Design 'D' motors. One is for motors with intermittent duty with slip, less than 5% for crane and hoist, the other is a motor with continuous rating but with higher slips, mainly required for punch presses. This application will be discussed at a later stage.

Design 'F'

Motors with low starting torque, low starting current.

The Design 'F' motor offers a low starting torque under direct-on-line starting (full voltage) and the starting current is restricted to a limited value and the slip is kept to less than 3 per cent. The pull-out torque is also comparatively low.

On account of the low starting and breakdown torque, the field of application of the Design F is very restricted. The motor is normally used to drive a light weight, such as high speed cutter heads in woodworking machines. The torque of the motor is only required to start and accelerate the load.

For different designs the starting torques and breakdown torques in per cent full load torques are given in Table 1. Figure 1 depicts the speed-torque characteristics of motors for various designs.

Special Duty Application of NEMA Design 'D'

When the drives require frequent starting/stopping or for high inertia load and for special duty cycle operation the Design 'D' motor, owing to its high starting torque characteristics, is ideally suited. The typical application of this type of machine is a Punch-press, where a high slip is essential.

The punch press motors have different types of slips. One motor is with slip 5-8 per cent and the other is with 8-13 per cent. The speed torque characteristics of these two types of slips are given in Figure 2. The maximum torque of the motor with high slip rotor is approximately 275 per cent of the full load torque and this is developed between 0 and 50 per cent of full speed. On account of higher slip the efficiency of the motor becomes less. For continuous duty motor, this condition is not desirable, where the load is of the pulsating type and the torque requirement is predominant, the relatively lower efficiency does not pose a great problem.

Depending on the operation of the punch press, high slip rotors are selected. The punch press operates over a wide range, some of them requiring 2 to 3

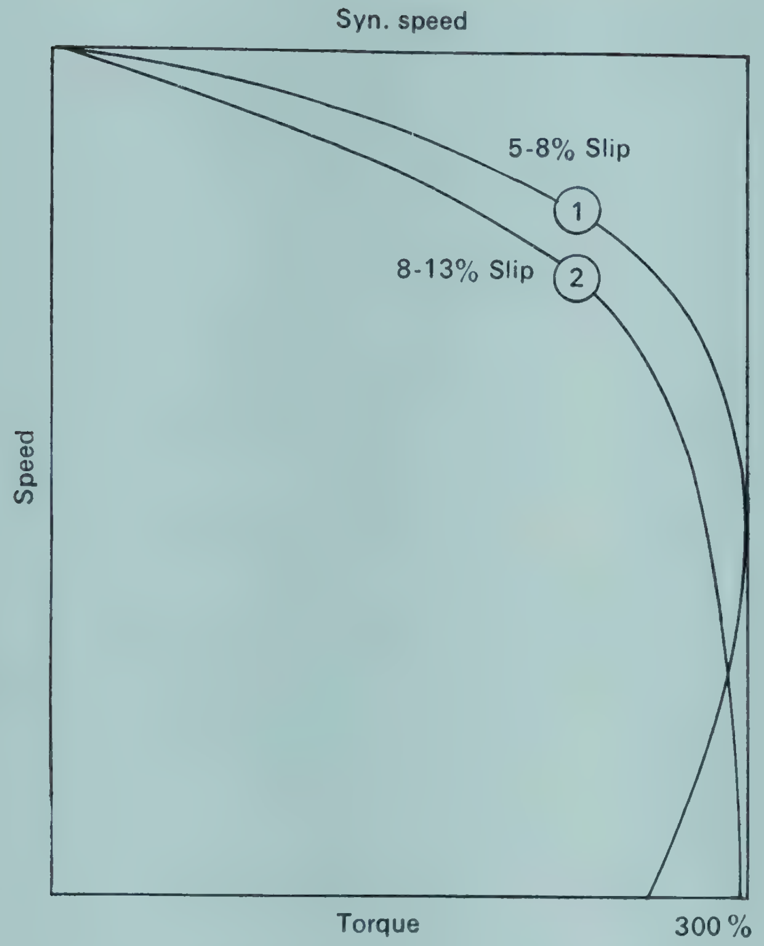


Fig. 2 Speed-torque characteristic of design D motors with two types of slips

work strokes per minute. Others operate as high as 100 to 150 strokes per minute. For very large presses involving a few strokes per minute, the motors with slip 8-13 per cent are employed. For presses with 10-40 strokes/min. the motor with 5 to 8 per cent slip is used. Where there is very little time for a flywheel to accelerate or decelerate, a standard motor with a slip of 3 per cent would be adequate for the application.

Classification of Rotors KL7—KL16h

The rotors are classified according to their ability to run upto speed against load. The torque of the motor must be sufficient to start against load and also to overcome any sudden jerks during operation. Siemens have developed different rotor classifications in order to meet actual demands of the loads under different operating conditions.

The rotors are designated as KL16, KL13, KL10 and KL7 etc.

The definition of the rotor class is as follows:

For instance, a KL16 rotor is so designed, that it can start and is capable of accelerating against a load torque equal to 160% of the full load torque, under DOL starting. In other words, the motor torque must be higher than the load torque, to produce high accelerating torque, to run up the driven machine from zero speed to full speed. It is to be noted that these are not the actual values of the torques but only rotor class in relation to the rated torque.

Moreover, KL16 rotor can develop a starting torque upto 250% of the full load torque, but the figure 160% is the guaranteed figure given for that rotor class. Similarly, KL13 rotor would develop a minimum load torque equal to 130% of the full load torque.

KL10 rotor would be capable of accelerating against load torque equal to 100% of full load torque.

KL7 would offer a minimum load torque of 70% of the full load torque.

For other rotor classes, namely, KL5, KL4 the similar definition will hold good.

The speed torque characteristics for different rotor classes are given in Figure 3.

For crane and hoist applications the cage motors with rotor class KL13h or KL16h are employed. These motors will start up reliably against a load torque of 130% and 160% respectively of the full load torques. For hoisting equipment motors do not normally need full speed for prolonged periods and as such slip losses do not have much importance. Therefore, it is possible to design the motors for a higher breakdown slip.

The starting torques of the motors are about 250-300% of the rated torque, and the starting currents approx. 450-500% of the rated current. The starting torque is the maximum torque obtainable within the range between zero speed to normal speed.

The rotors must be so designed that the starting current is low, the accelerating torque high and efficiency good. To obtain these requirements there are various designs of rotor constructions, namely deep-bar, double cage and Silamin rotor for KLh.

Comparison of NEMA Design Classes A—F with Rotor Classes KL7-KLh

With the different rotor designations KL7 to KLh,

the wide selection of starting torques and currents can be obtained.

These speed torques are comparable with those obtained with NEMA A—F designs.

(1) NEMA designs 'A' and 'B' motors are with deep bar rotors. The starting torques and starting currents obtained in these rotor designs are similar to those offered by KL10, 13 and 16 classes.

(2) NEMA design 'C' motors are with double cage rotors. The starting torques and current obtained in this rotor design is similar to that offered by KL13 and KL16 rotor classes.

(3) NEMA design ' D ' motors are with high resistance rotors (slots smaller and wide). The starting torque obtained is approximately 2.75 times the full load torque and high slip. This type of starting torque characteristic can be obtained by specially designing the rotor with material of low conductivity, for high slip and high starting purpose KLh are offered.

(4) NEMA design ' F ' motors are with double cage rotor suitable for lighter starting conditions and for smaller ratings. There is no equivalent type of KL rotor designation. However, the speed torque characteristics can be obtained by KL7 rotor.

Table 1 NEMA Classifications

Design	Starting torque in % of rated torque	Breakdown torque % of rated torque	Slip %
A	150 — 180	220	< 5
B	150 — 180	200	< 5
C	200 — 250	190 — 225	< 5
D	275	275	5 — 8
F	125	135	< 5

Table 2 KL designed Rotor Classifications

Rotor class	Starting torque in % of rated torque	Breakdown torque in % of rated torque	Slip %
KL 7	125 — 135	140	1 — 3
KL 10	150 — 180	200 — 250	1 — 3
KL 13	200 — 220	200 — 230	1 — 3
KL 16	240 — 260	210 — 230	1 — 3
KL h	275 — 300	275	4 — 6

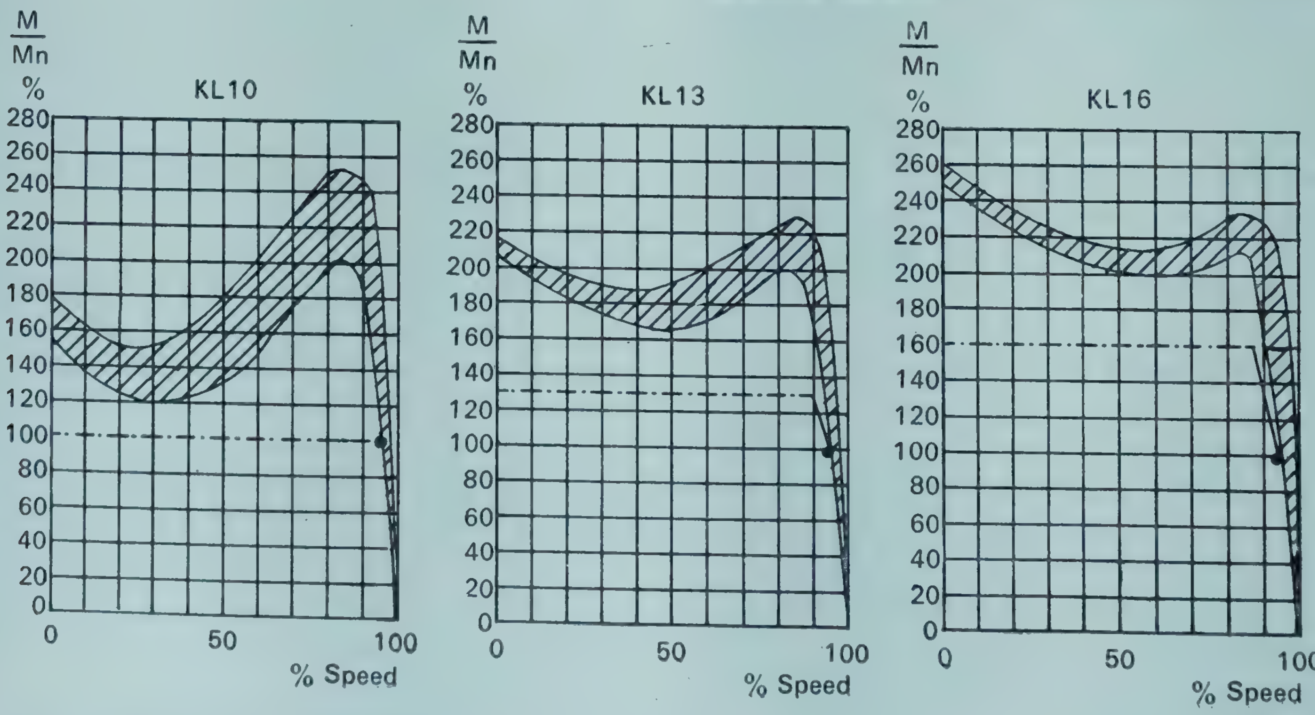


Fig. 3 Speed-torque characteristics for different rotor classes

Applications of Various Types of KL Rotor Classes

The employment of various types of rotor classes for different drives under a wide range of starting conditions are given in Table 3.

Table 3

Drives	Starting Conditions	Suitable Rotor Classes
Machine tools viz. centre lathes, milling machines and grinders	These in general have some declutching device and the moment of inertia is low.	KL 10
Centrifugal pumps, fans and blowers	Starting torque is normal. The loads are without high moment of inertia.	KL 10
Exhausters and Calendar drives	Starting torque is normal.	KL 10
Reciprocating pumps	This has a high starting torque since it has to overcome the friction due to tight pump glands and friction of the piston in the cylinder.	KL 13 or KL 16
Compressors	The starting torque is normally 2 to 2.5 times full load torpue.	KL 13 or KL 16
Conveyors	Starting load consists of the weight of the materials and bearing friction.	KL 13 or KL 16
Disintegrators, Crushers, Extractors, Pulverisers etc.	These have to accelerate high inertia loads although friction to be overcome is low.	KL 16
Rolling mills and Sugar Centrifuges	High starting torque.	KL 16
Winches, Crane and Hoist	Starting torque high, frequent operation, intermittent duty.	KL h

Conclusion

For several decades the cage type of induction motor has been considered as the simplest type of electrical motor, due to its robust construction, reliability in service with little maintenance in operation. Continued design developments have made it possible to attain different rotor characteristics in the motors, which have subsequently been applied to various drives to fulfil their starting requirements.

PLANNING A MOTOR CIRCUIT—VIII

CONTROL AND SIGNALLING DEVICES (contd.)

—V. S. BHATIA

As already stated in Part VII of this series of articles, signalling devices serve as a useful complementary product to control devices, such as push buttons. They may be in the form of signalling lamps installed separately, adjacent to the push buttons or combined together in the form of luminous push buttons, see Figures 1 and 2. They are available in different colours and of matching dimensions to those of push buttons.

Function

Signalling devices can be used to perform the function of either "indication" or "confirmation". As far as luminous push buttons are concerned, only the common types which show only one and the same colour when illuminated or when dark, and which return to their reset position by themselves when released, are considered here.

(i) Indication

Signalling lamps serve to attract the operator's attention, Figure 3, and/or to indicate that he should perform a certain task. When a luminous push button is lighted, it shows the operator that he may or should press the lighted button, or in certain applications he should perform a certain task and then press the button. The reception or execution of the order (which has been given by pressing the button) is confirmed by the extinction of the light, Figure 4. In other words the sequence is: first light, then push the button.

A flashing light may be used in order to attract the attention of the operator, for example in case of alarm. When used in such a way, the pressing of the button may change the flashing light into a steady light. The steady light then remains on, until the cause of the alarm has been eliminated by separate action.

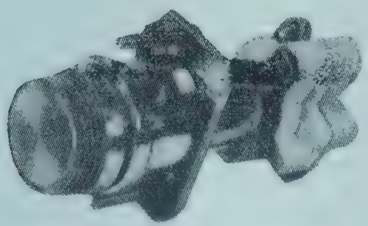


Fig. 1 A signalling lamp

Fig. 2 A luminous push button

(ii) Confirmation

The signalling lamps serve to confirm a command, a state or condition or to confirm the termination of a change or transition period. When an unlighted luminous push button is pressed, it lights up as a confirmation that the order (given by pressing the button) has been received or executed, Figure 5. In other words, the sequence is: first push the button, then light.

Luminous push buttons may be used with a flashing light in order to give a "double confirmation": When the button is pressed, the light starts to flash to

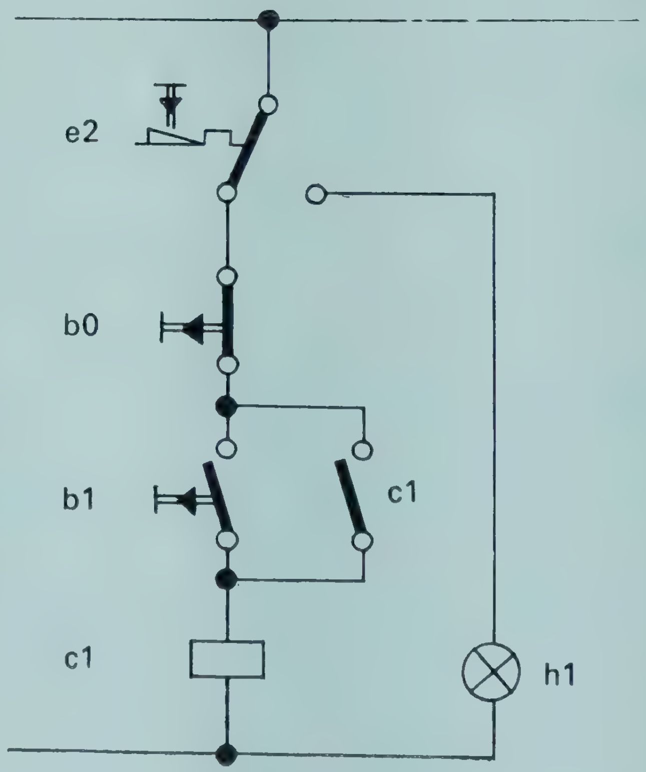


Fig. 3 The circuit of a starter with: bo=stop push button b1=Start push button, c1=Contactor, e2=overload relay trip contacts, h1=signalling lamp.

When overload relay e2 trips the contactor c1 drops but the signalling lamp h1 lights up indicating the occurrence of overload.

confirm that a starting operation or sequence or a transition period has been initiated. When this has completed, the light automatically changes to steady, to confirm that normal running conditions have been established.

Significance of Different Colours

As in the case of push buttons, only selected colours of signalling devices can be used to convey different functions. According to international understanding, the colours: red, yellow (amber) and green have been assigned specific meanings as per column 2 of Table V. These three colours are not to be used for any other meaning. Instead blue or white (clear) colour can be used for other meanings. Typical applications are given in Table V.

The significance of the colours of luminous push buttons are given in Table VI. This, in fact, is a general guidance for application of luminous push buttons for Machine Tools. However, for other applications similar pattern can be used. Only the colours red, yellow, green and blue should be used for the purpose of indication, but not white. On the other hand for the purpose of confirmation, generally the colour white (or clear) should be used. If other colours are used, it should be ensured that they do not lead to confusion. Generally, it is safer to use a neutral white colour in case there is a difficulty of assigning any other specific colour. Furthermore, it is recommended that luminous push buttons should not be used for "emergency stop" function. This is because the life of the bulbs is limited. A failure of the bulb can lead to incorrect conclusions, just when the information which the light should give, is urgently needed.

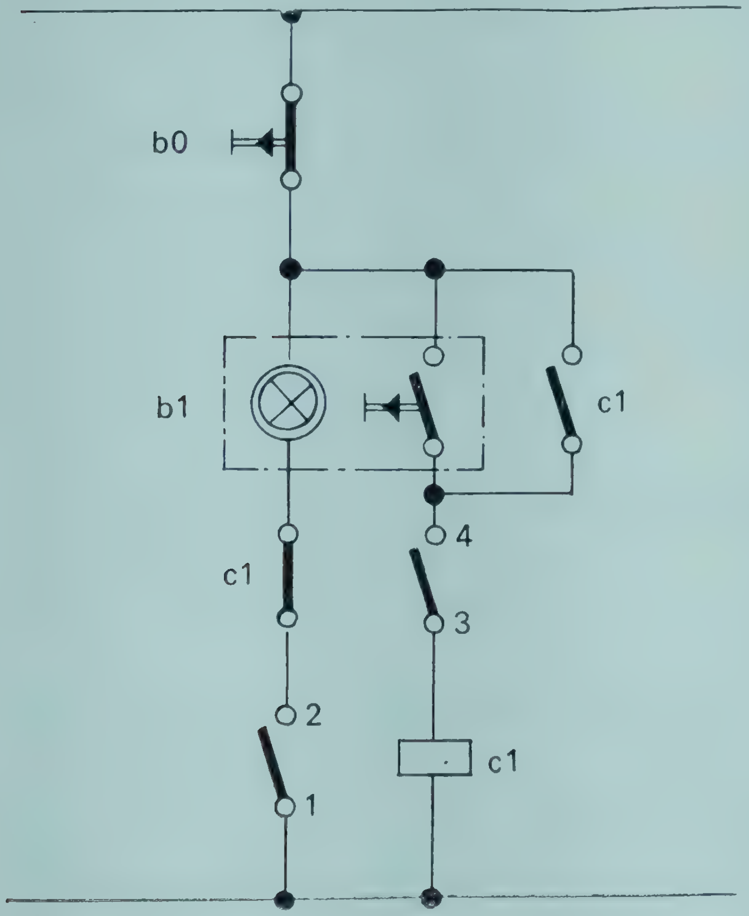


Fig. 4 As soon as sufficient oil pressure is built-up the contacts 1-2 and 3-4 of the Pressure Switch close. The bulb inside the luminous push button b1 lights up indicating that the machine can now be put into operation by pressing the button b1 which then will energise the contactor c1 and simultaneously switch off the light.

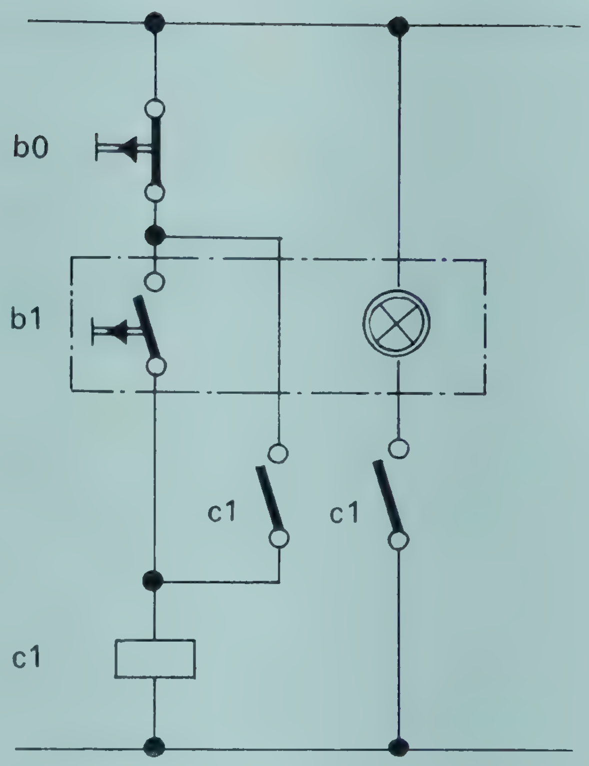


Fig. 5 On pressing the luminous push button b1, the contactor c1 picks up and also closes the circuit for the bulb within the luminous push button, confirming the execution of the command.

Design

It is amply clear from the above that any good design of a signalling device must provide :

- Clarity of colour
- Sufficient intensity of light
- Reasonable degree of operational surety.

Table V **Colour Coding of Signalling lamps**

1	2	3	4
Colour	Meaning	Explanation	Typical applications
Red	Danger or alarm	Warning of conditional danger or a situation which requires immediate action	Failure of pressure in lubricating system Temperature outside specified (safe) limits Essential equipment stopped by action of a protective device
Yellow (Amber)	Caution	Change, or impending change of conditions	Temperature (or pressure) different from normal level Overload, the duration of which is permitted for limited time only
Green	Safety	Indication of a safe situation or authorisation to proceed, clear way	Cooling liquid circulating Automatic boiler control in operation Machine ready to be started
Blue	Specific meaning assigned according to the need in the case considered	Blue may be given any specific meaning which is not covered by the three above colours: red, yellow and green	Indication of remote control Selector switch in "Set up" position
White (clear)	No specific meaning (neutral)	Any meaning, especially confirmation. Can also be used whenever doubt exists about the application of the three colours: red, yellow and green	Indication of positions or state Equipment working Motor or machine running Synchronizing lamps

Note : For abnormal conditions requiring immediate action or attention a flashing signal of the appropriate colour may be used, accompanied by an audible signal if desired.

The combined effect of the lens provided on the signalling device and the bulb used must be considered to ensure the above requirements.

(a) Bulb

Signalling devices may be provided with incandescent or neon bulbs. To make a choice one must study their relative advantages and disadvantages. Some of the important ones are given in Table VII.

It is not difficult to make a choice depending on the conditions of installation. For example, for locations, subject to excessive vibrations, it is preferable to use a neon bulb, provided other conditions like colour or supply voltage do not prevent its usage. In case an incandescent bulb has to be used for such applications, it is better to select a bulb of a lower voltage which has a more stable filament. Additionally, precaution can be taken to select a bayonet type of bulb since the screw type is likely to get loose due to vibrations. Likewise, one will have to select an incandescent bulb for installations located under bright light, or where the signalling lamp has to be observed from a distance.

Table VI **Colour Coding of Luminous Push buttons**

Colour	Mode of use	Signification of the lighted button	Function of the button	Examples of application and remarks
Red	Indication	Abnormal conditions requiring immediate action by the operator.	'Stop' and in some instances 'Reset' (only if the same button is also used for 'Stop').	Order to stop the machine immediately (e.g. because of an overload) or to indicate a protective device has stopped the machine (e.g. because of an overload, over-travel or another failure).
Yellow	Indication	Attention or caution.	Start of an operation intended to avoid dangerous conditions.	Some value (current, temperature) is approaching its permissible limit. Pressing the yellow push button may override other functions which have been selected previously.
Green	Indication	Machine or unit ready for operation.	Start after authorisation by the lighted button.	Start of one or several motors for auxiliary functions. Start of machine elements. Energising of magnetic chucks or plates. Start of a cycle or a partial sequence.
White or Clear	Confirmation	Permanent confirmation that a circuit has been energised. Or that a function or a movement has been started or pre-selected.	Closing of a circuit or Start or pre-selection.	Energising of an auxiliary circuit not related to the working cycle. Start or pre-selection. — of direction of feedmotion. — of speeds etc.

(b) Constructions

The material used for a signalling device should be such that it can withstand the heat generated by the bulb. Furthermore, the design should provide adequate ventilation, in case the signalling device permits the use of high capacity bulbs.

The lens of a signalling lamp should be so designed.

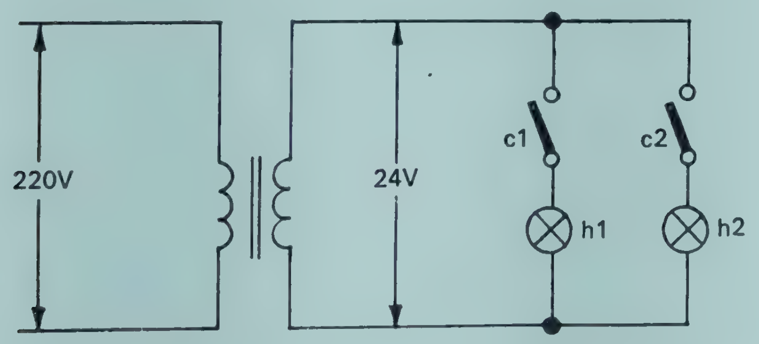


Fig. 6 Circuit of a common control transformer for a number of signalling devices

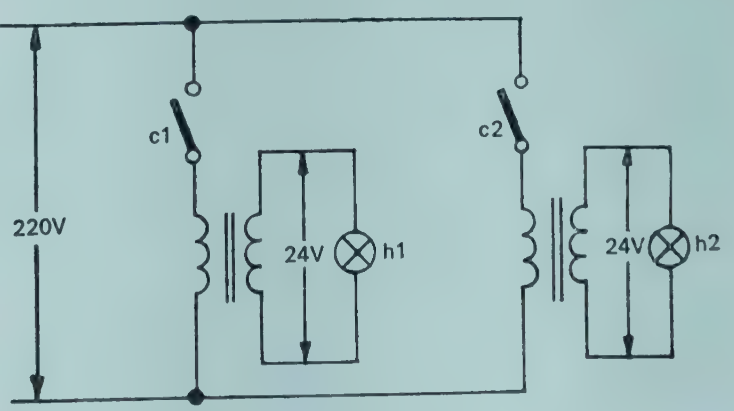


Fig. 7 Circuit of individual control transformers for each signalling device

Table VII **Application of Neon-incandescent Bulbs**

Requirement	Neon Bulb		Incandescent Bulb	
	Feature	Consequence	Feature	Consequence
Clarity of colour	Emits reddish-yellow glow	Cannot be used for blue and green signalling lamps	Colour of the lamp unaffected by the light emitted	Can be used for signalling lamps of all colours
Intensity of light	Low	May not give clear indication when seen from a distance or under bright surroundings	High (Depending on output)	Gives better visibility
Current consumption	Low	Economical and does not affect other equipment due to its heat	High (Depending on output)	Less economical and likely to affect other equipment by its heat
Sensitivity to shocks or vibration	Not so sensitive	Can be used for every type of installation	Sensitive	Likely to get damaged at installations subject to excessive vibrations/shocks
Sensitivity to voltage fluctuations	Negligible	Longer life	Sensitive e.g., 10% increase in voltage reduces life by about 70%	Should be used on systems with relatively steady voltage
Life expectancy	High	Practically no replacement required	Limited	Replacement necessary
Rated voltage	Usually available for 110 or 220 V	Cannot be used on lower voltages	Available for different voltages upto 250V	Selection possible according to requirement

that it prevents glare from the bulb; also the lens should preferably be dome shaped to permit visibility from all directions. The material used should be such that it neither gets distorted nor changes colour due to heat from the bulb.

(c) Control Transformer

It has been stated above that, generally it is advantageous to use a low voltage bulb. In many applications it will then become necessary to step down the supply voltage to the bulb voltage. It is possible to have a common transformer for a number of lamps, Figure 6, or an individual transformer for each signalling lamp, Figure 7. Since it is disadvantageous to operate the switching devices at low voltage, the use of individual control transformers provides a better arrangement. Extra cost must, however, be taken into consideration. The use of a resistor to reduce the voltage is not recommended, since it produces additional heat and its failure will also damage the lamp.

(The next article in this series will conclude the theme on Control Devices.)

—P. JAIN

Events in all fields of sciences are moving so fast that one needs a constant feed back regarding new developments. This feed back is all the more necessary in existing automatic plants employing the latest instruments and gadgets and as such the importance of physical observation of certain vital process spots still remains established. What the naked eye can not achieve by observation of special spots in the plant, which are of interest for production flow and are inaccessible on account of extreme conditions (e.g. heat, cold, gas, radio-activity etc.), can very well be achieved, in much greater proportions, and supervised continuously without any health hazards with the help of a simple television installation.

A few examples can be cited out of many, of effective utilisation of closed circuit television installation and representations could be drawn from power plants, rolling mills, cement mills, reactor plants and the medical field.

In power plants there are three important points which are worth keeping under observation—the burners, the boiler drum water level and the stack of the power station chimney, independently of the degree of automation, which exists in the plant. The observation of the burners with the help of a probe-lens camera fitted in the boiler wall ensures a steady air supply and accordingly the best utilisation of the fuel, to be checked by the shape of the flames. Even if the automatic boiler regulation sees to it, that the water level never sinks below the admissible level, the water level can not be checked too often. However, the TV installation provides a complete observation of the water level in a control room. The observation of stack in the power plant by the TV camera gives indication about the combustion. The condition of no smoke means efficient combustion and clean air.

The application of a TV system in a power plant is depicted in Figures 1 and 2.

In continuous production plants, process parameters are centrally supervised and regulated. However, at certain critical points an additional visual check is essential with the help of a TV camera, such as in the case of the sintering of raw meal in a cement kiln. This enables any damage to the kiln lining to be recognised in time and checked thereby preventing

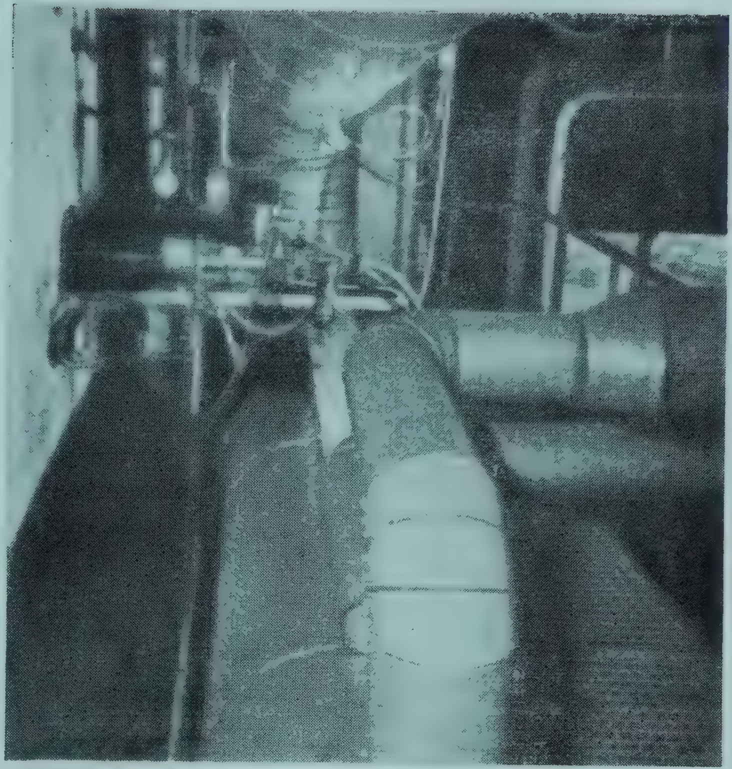


Fig. 1 A probe-lens camera in the boiler wall

down-time. In a Cement Plant, the sintering material in the rotary kiln and in the clinker cooler is observed centrally and simultaneously through a TV installation. The furnace probe-lens camera with its lens aperture is inserted far enough into the kiln, thus providing visual monitoring of the raw meal flow, the kiln lining and the unfavourable depositions. These applications in cement industry are shown in Figures 3 and 4.

For Rolling Mills, there is no better way to follow the route of ingots from a central location than with the help of a TV installation. The position and movement of the slabs in the pusher furnace can be checked through a furnace probe-lens camera. The slabs always remain in the field of vision of the cameras while moving towards the roll stands on the roll table. As the slabs pass on to further processes, as in the sheet pickling train, the control of the entire pickling process is brought about by observation of the process on the monitor, in a central control room. The TV installation can also keep a constant eye on critical points such as the coiler.

The utilisation of the TV system in a Rolling Mill has been depicted in Figure nos. 5 and 6.

In reactor engineering the safety in two respects is of

paramount importance. The first being the safety of the reactor and secondly the safety of its operating staff. Every equipment of the plant is conceived with these two features in mind. In most of the reactor plants the reactor pressure vessel must withstand high pressure say upto 120 metric atmospheres or more. Therefore, the lid of the reactor is welded in addition to screwing it down, thus ensuring absolute tightness. When the lid is to be opened, the important processes involved are welding and cutting, which are remote controlled. The TV cameras are mounted near the tools utilised for welding and cutting and transmit the image of the welding electrode and that of the milling tool to the monitor kept at a central location.

Such a utilisation of the TV cameras and monitors in reactor engineering has been depicted in Figures 7, 8 and 9.

With the advance in the medical field, new techniques —especially in surgery—are spectacular. News regarding the replacement of organs of human body has become a common affair. To keep a close watch on these developments and to demonstrate the new and otherwise important techniques to young doctors under training, close circuit television plays a vital role. It serves wonderfully as a feed back medium for experts, to keep a track on latest developments with the aid of video recording and as a unique aid for doctors under training, to visualise intricate operations by senior experts in greater details.

Fig. 2 Stack observation

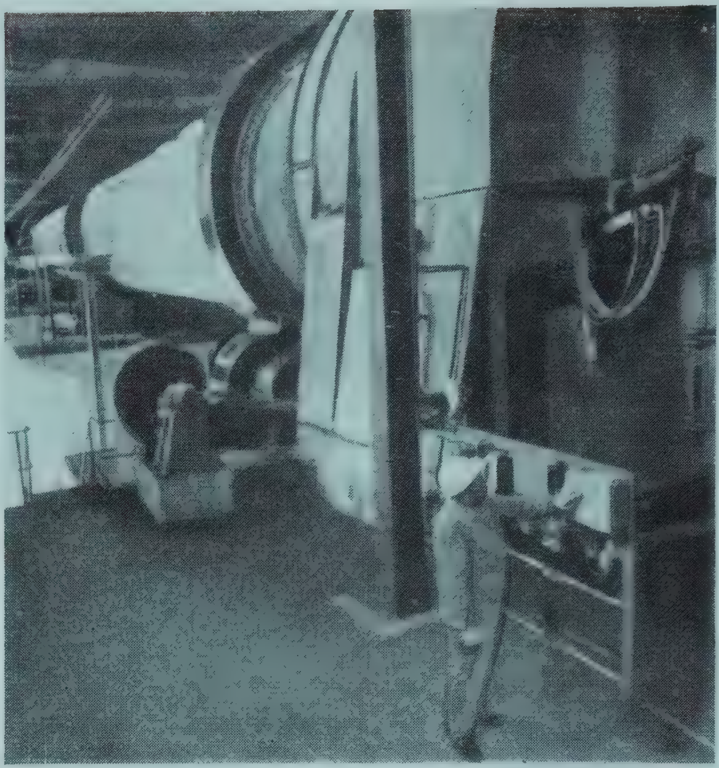


Fig. 3 Observation of rotary kiln

A lot of progress has been made in television systems and todays' equipment is the outcome of many years of research and experience. Development led from tube equipped systems via the use of germanium transistors to equipment using silicon planar transistors. The transistor technology brought about units offering smaller dimensions, reduced weight, lower power requirements and thereby lower heat development. It was however, only with the advent of silicon transistors in planar technology—which are distinguished by their reliability, independence from temperature changes, low scattering in their operating data and long useful life, that the good properties found in tube technology were equalled and surpassed.

The use of plug type modules with printed circuits and silicon planar transistors resulted in a variable system with excellent quality, a high degree of operating safety and simple maintenance.

Modern closed circuit TV equipment utilises the

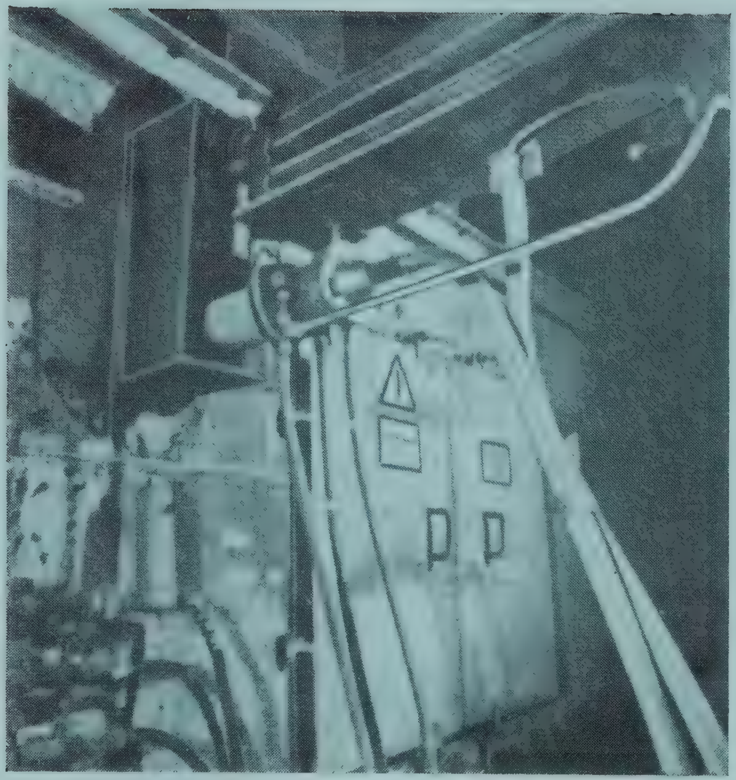


Fig. 4 Observation of clinker cooler

building block principle incorporating developments explained above. The equipment is coupled to a suitable operation microscope whose choice depends upon the utilisation i.e. whether it is being used for general survey, opthalmology or neuro-surgery etc. Figure 10 shows a closed circuit TV system with an operation microscope. The system consists of the following basic units:

(a) TV Camera

(b) Monitor

(c) Pulse control unit and operating console.

These units have been shown in Figure 11 depicting a simple closed circuit TV system. The system has the choice of either being monochrome or coloured. The colour television system guarantees a screen image in natural colours. This represents a significant, if not decisive, increase in the information content besides the other obvious advantages which need not be elaborated.

The inter-connection between the above basic units is very simple, reliable and requires little maintenance. What is required is only a coaxial cable to establish connection between the various units.

A brief description of these units is as follows:

TV Camera

Latest designs offer a TV Camera—the core of a TV installation, which distinguishes itself with:

Compact design

Low weight

Simple manipulation

Low heat generation

The camera incorporates fully automatic light sensitivity control or optimum adaptations to varying light conditions and 3-interconnected regulating systems viz., automatic gain control, automatic target voltage control and automatic control of lens diaphragm.

The camera can be equipped with suitable accessories like weather proof camera casing, pan and tilt units for the camera and pan and tilt units in low noise design, tripod, operating and control consoles etc. for a specific application. The TV camera can be equipped with:

Vidicon, quality 1, 2 and 3.

Plumbicon, quality 1, 2 and 3.

Silicon, multidiode, vidicon, quality 1, 2 and 3.

When the camera is equipped with a plumbicon or multidiode vidicon tube, no control of signal electrode voltage is possible, but amplifier gain control and automatic iris control, are effective.

The compact camera has the choice of the following lenses depending upon the exact application:

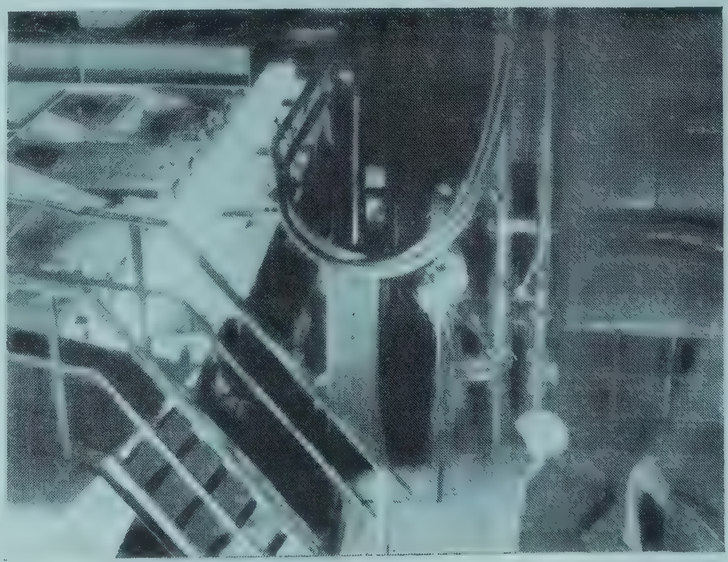


Fig. 5 Observation of slabs in the pusher furnace

Fig. 6 Coiler observation

Lenses with fixed focal length:

without motor drive, for manual adjustment of iris and focus,

with motor drive for iris, for remote control of iris or operation with automatic iris and manual adjustment of focus,

with motor drive for iris and focus, for remote control of iris and focus or remote control of focus and operation with automatic iris.

Lenses with variable focal lengths (zoom lenses) can also be provided, without motor drive for manual control of focal length, iris and focus and also with motor drive for remote control of focal length, iris and focus, or remote control of focal length and focus and operation with automatic iris.

The camera is supplied with a simple attachment (an optical link) which facilitates its connection to an operation microscope. The camera picks up the magnified image and transmits it through the associated equipment to the monitor for picture display and/or video recording.

Pulse Control Unit

Generating, shaping and mixing of the control pulses, amplification of the video signal fed from the camera, mixing of the amplified video signal with the pulses required for brightness, modulation and synchronization of the monitors, adaptation of the sensitivity of the pickup tubes to the actual ambient illumination by built-in automatic light figure selector, are some of the essential functions of the pulse control unit. The unit can be complemented by video pre-equaliser, for video transmission overlong cable distances.

The pulse control unit may be provided with a camera changeover unit by which the cameras are connected optionally to the input of the control unit; thus, providing that one particular camera, as desired, feeds the monitor. The changeover unit contains the necessary relays for the video and control lines. For this use, operating consoles are utilised with an appropriate number of camera selective buttons.

In medical colleges a number of operation theatres exist for specific operations of equal importance. So by providing a camera in each operation theatre, an arrangement can be worked out with the help of a changeover unit and operating console, that one particular camera feeds two monitors, one mounted in the visitors' gallery and the other in the doctors' room. However, this is only one of the solutions of this requirement.

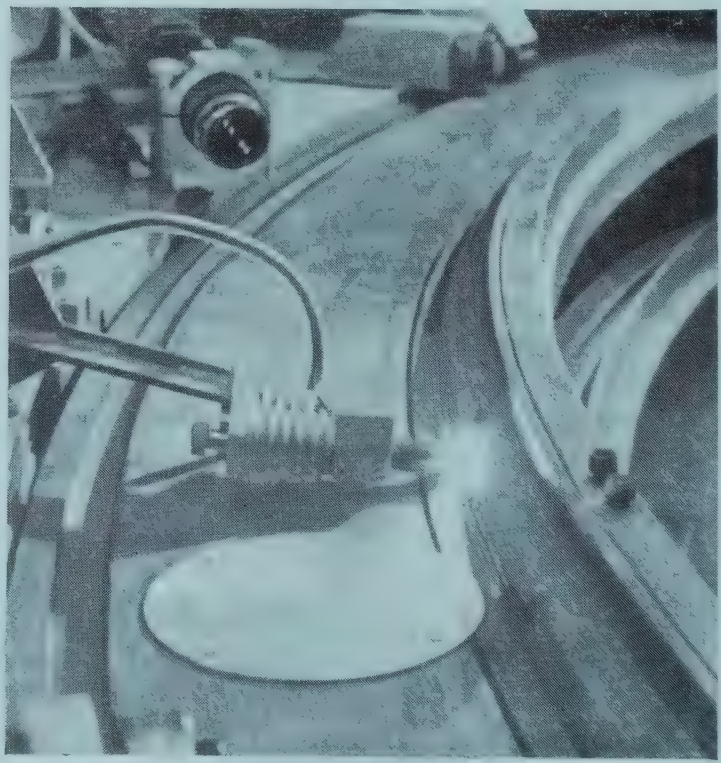


Fig. 7 Observation of welding process

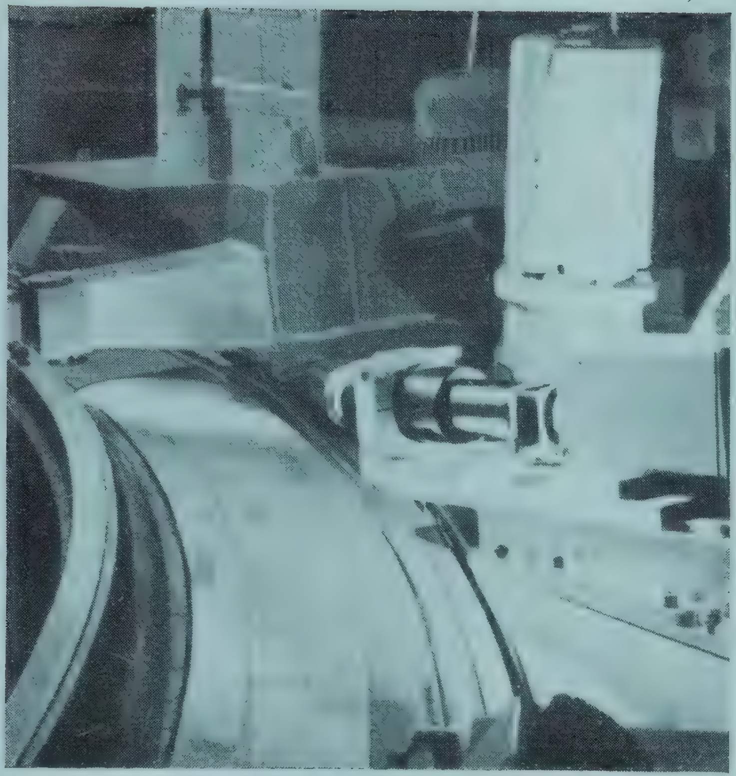


Fig. 8 Observation of milling process

In big medical institutions a number of operation theatres are planned and constructed. Hence the utilisation of a number of cameras, one for each theatre, calls for more finances. Moreover, there are restrictions with regard to the cable distances between the camera and the control unit, the control unit and the monitors. The maximum length of the cable between the camera and the control units is 300 M and for the cable between the control unit and the farthest monitor about 500 M. Larger distances may however be spanned by special cables, video amplifiers or with the aid of carrier amplifiers. To overcome this problem, a system can be offered in the following manner, incorporating an electronic cross-bar, thereby arriving at an optimum camera number and required monitors, thus cutting on the finances required.

In this system the television camera is fixed on a mobile tripod with tripod trolley and is portable. The pulse control unit belonging to the camera is mounted on a mobile trolley also. Advantage is taken of the fact that only a coaxial cable establishes connection between the control unit and the monitors. As such a simple coaxial jack is sufficient to be provided in each operation theatre.

The mobile camera along with trolley and control unit can be moved from one operation theatre to another and outgoing connections put into the coaxial jack provided in each operation theatre. The incoming lines from sundry operation rooms can be applied to an electronic cross bar distributor. The electronic cross bar distributor has been shown in Figure 12 which is a model representation of the system and not the actual system. The respective TV pictures can be transmitted to the auditorium or any other observation post via a control desk.

Monitor

The monitor has the function of displaying pictures which have been transformed in the camera into electrical pulses. The monitors should produce television pictures of high brilliance and resolution. Modern monitors are made from polyurethane structural foam in attractive styles which gives them a high mechanical strength at a low weight. The use of special high grade components should be made to ensure a long life even at continuous operation ‘round the clock’ and unfavourable conditions of use. It is recommended that the monitors are provided with a darkening circuit so that in the absence of video signal, the picture tube is blanked and thus

Fig. 9 Observation in control room for welding and milling processes

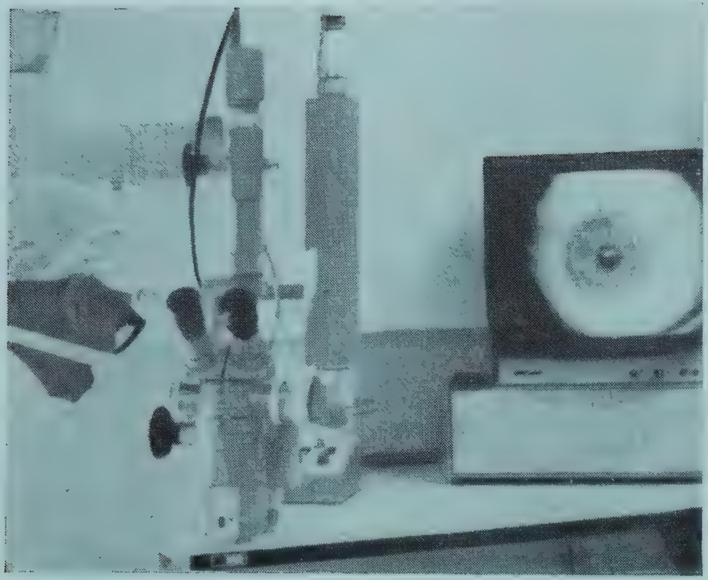


Fig. 10 Monitor displaying picture via an operation microscope

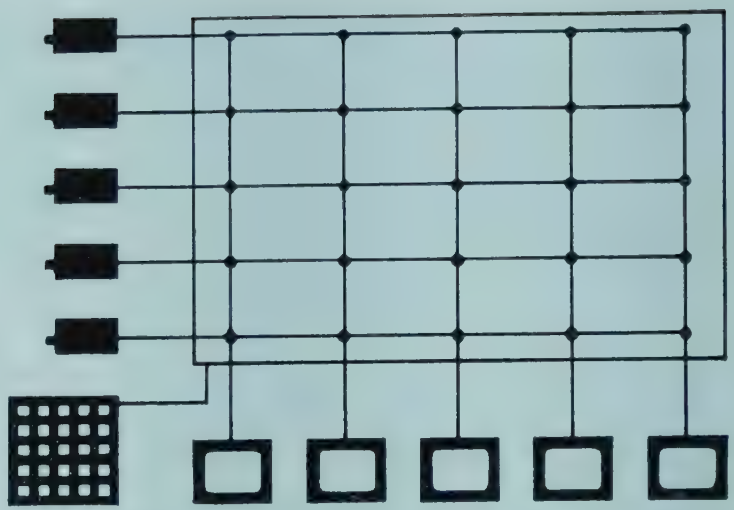


Fig. 11 General layout of a large CCTV system

saved. For this purpose the monitors are provided with a black-out switching unit, if—in systems with a video distribution system, for instance, the composite video input signal is likely to be absent from time to time, though the equipment must remain ready for use. When the composite video signal is absent the black-out switching unit prevents disturbing flashing on the picture screen; and also prevents contamination of the picture tube cathode. The choice of screen size of the monitor is determined by the distance from the observer and the number of observers.

1. 17 cm small screen size video monitor for a viewing distance of 0.5 to 0.8 metres. This size is ideal for a table top unit.
2. The 44 cm medium screen size video monitor is well suited for observation and supervision functions at a viewing distance of 1.5m to 2.2m.
3. The 61 cm screen size video monitor is mainly used for educational and advanced training in large teaching rooms and is applied to viewing distance of 2.5m or more.

However, the exact size can be recommended after assessing the requirement. Video tape recorders can be incorporated in the monitors, to record the pictures. Installation of this equipment can be most useful in the medical field, in keeping track of latest developments in operation skills, and in supervising and controlling important processes in different industries.

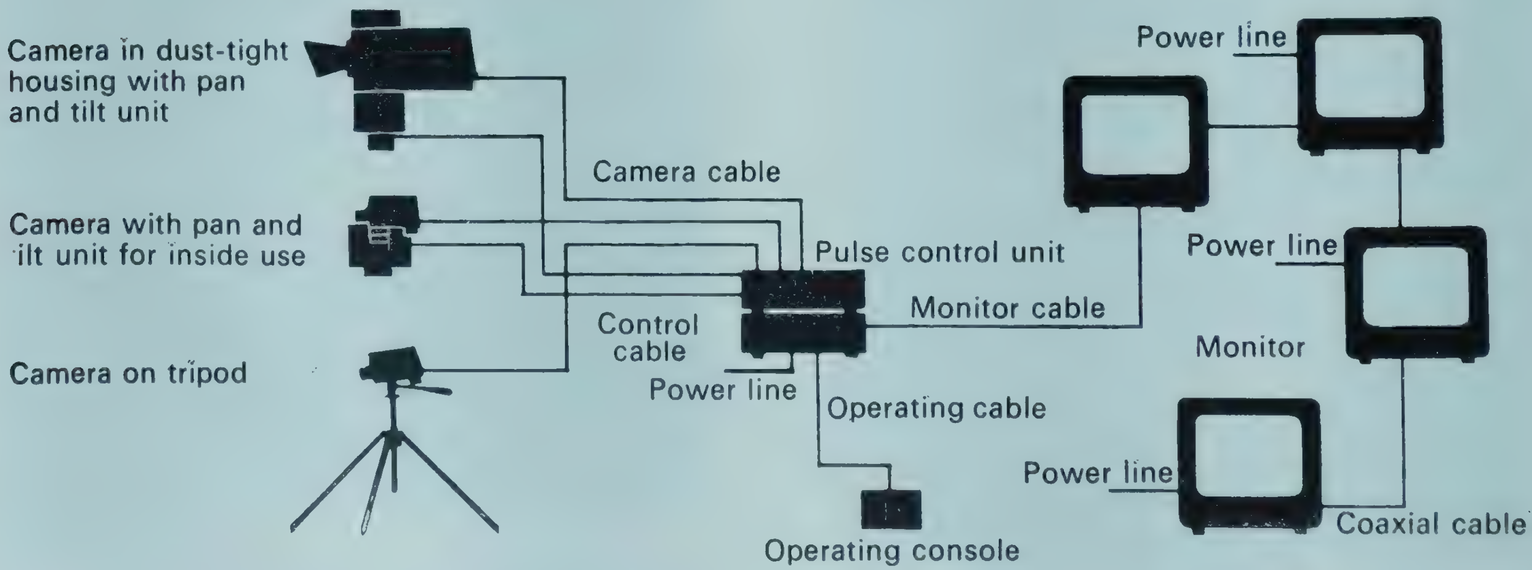


Fig. 12 Electronic Cross Bar distributor and selector keyboard

Environmental protection for electrical equipment

Whenever there is talk of the harmful effects of atmospheric pollution, the victims are usually human beings, animals, or buildings and monuments. But technical equipment suffers increased wear and tear in this way too. This applies above all to electrotechnical devices and components which are so clean in themselves but are often badly damaged by the many pollutants in the air.

In order to acquire reliable data on the performance of electrotechnical equipment when used in polluted air and thus to be able to initiate remedial measures before it is too late, Siemens has now developed new testing methods, since conventional methods of testing industrial atmospheres no longer satisfy present-day requirements.

Until now, studies of environmental influences on electrotechnical equipment have usually been confined to tests carried out in extreme climatic conditions such as those encountered in natural environments (e.g. cold, heat, humidity, under-pressure, mould growth and salt mist). Nowadays, however, the air pollution caused by technology must also be taken into consideration, especially as growing miniaturization, compact structure and complex function are inevitably accompanied by increased sensitivity of the components and equipment. According to reliable information in various publications, 2.5 million tons of dust and nitrogen compounds, 3 million tons of hydrocarbons, 5 million tons of sulphur oxides and 7 million tons of carbon monoxide find their way into the air every year in the Federal Republic of Germany alone.

At Siemens the problem of industrial atmospheres has been studied for many years in countless series of experiments, and this gradually led to the establishment of criteria which are held to be a suitable basis for future standardization. For testing communications, switches, plugs and PC boards, for instance, the following sequence has proved suitable: 5 days exposure to dust with $6_{g/m}{}^2$, followed by 10 days climatic testing with 10 ppm SO_2 and then another 10 days with 1 ppm H_2S. In experiments on relays, telephone components, plug-in connectors and switches, the parameters listed in the table below led to easily differentiable results.

A free-sedimentation method for studying the effects of dust on communications components was devised at Siemens years ago and has since been recognized by the Deutsche Bundespost as an acceptance inspection test in certain development projects. Moreover, it was entered as the German proposal at the International Electrotechnical Commission (IEC). The test dust recommended by Siemens, which always has the same composition and particle-size distribution, has a high proportion in the particle-size range below 5_{μ}m and also contains an admixture of 3% cotton linters to simulate the natural abraded particles of clothing. According to the experience gained at Siemens, the amount of test dust introduced should be such that approximately $6_{g/m}{}^2$ settle in the test chamber daily.

To test industrial atmospheres Siemens employs both a stationary method and a continuous flow method. In the case of the stationary method the test air is renewed only once a day. All that this method requires is a corrosion-proof chamber made of synthetic material or high-alloy steel, whose interior is kept at room temperature (approx. 23°C).

In the Siemens laboratories the test air in the experiments described above is examined by two different methods, depending on the objectives and the accuracy required. The automatic electric gas analyzers used accurately register gas constituents well below 1 ppm, while in the relatively simple test tubes used—which are filled with a special test salt—the length of the colored zone is a measure for the concentration of noxious gas. In the latter case, however, the risk of individual reading errors and other inaccuracies are relatively great.

Gas component	H_2S*	SO_2*	NO_x*
Temperature °C	23 or 40	23 or 40	23 or 40
Relative humidity % ..	83	83	83
Concentration ppm ..	1	10	1
Duration of test (days) ..	4, 10, 21	4, 10, 21	4, 10, 21

* H_2S = hydrogen sulphide SO_2 = sulphur dioxide NO_x = nitric oxides

Clean the brush supports and brush holders in regular time intervals, according to the degree of contamination, during standstill of the machine.

At the same time the following checks should be made:

Check all terminal screws in regular time intervals for good contact. Poor contact may cause the flex to glow out.

Check whether the brushes can move freely in their brush guides and are not stuck in any place (especially with split brushes, split brushes with a wedge top and with brushes bonded with synthetic resin).

Checking the Brush Wear

Brushes may be worn away to a rest of 40 or maximum 30% of their initial height. The utilizable height varies somewhat depending on the type of brush and brush holder. Normally the residual height should not decrease below 17 to 15 mm.

The brushes in hinged brush holders should be replaced when the brush protrudes approx. 6 to 5 mm above the brush socket. The exact values should be asked from the machine works.

With brushes fitted with a piece of flex for connection, a tightening of the flex is a sign that the brushes have to be replaced soon. When the brush is taken out of the brush holder for measuring the height of the brush or for cleaning the brush holder or similar, take care to put the brush back into the same holder and, with regard to the fitted contact surface, not to put it back twisted around by 180°.

Brush Replacement

When all brushes of one or several brush studs or brush support bars are replaced simultaneously, the new brushes must be properly seated in any case.

If only one brush has to be replaced because it is badly worn, it may be replaced if necessary without grinding (e.g. if the shutdown interval is too short for the grinding operation).

With new machines or with machines which have been reinstalled in a new place with other ambient conditions (other humidity of the air, gases etc.) it may be necessary to replace the brushes sooner than expected during the first time of operation, since the film on the commutator or slipring surface takes some time to built up. If it is intended to make wear measurements (mm brush wear per 1000 hours of operation), these measurements should only be started after the film has been properly established.

Repeat Order of Brushes

It is recommended to keep one full set of spare brushes in storage in order to prevent interruptions of the operation. Since the working reliability of a machine depends to a considerable extent on the quality of the brushes, it is recommended to use only the original make of brushes (any change in the make and grade of the brushes should first be discussed with the machine works).

Use of Lubricants

Brushes are provided during production with an accurately proportioned quantity of lubricant. Any additional lubrication of the commutator or an impregnation of the brushes may lead to failure and should normally be avoided. Generally the brushes should operate properly without any assistance.

If, in exceptional cases vibrations of the brushes do occur, which especially during no-load running can lead to brush noises or heavy brush chattering, this can be remedied (most times only for a short period) by carefully applying a suitable lubricant (acid free paraffin) to the commutator surface. In order to obtain a proper distribution of the lubricant, it is recommended to apply the lubricant to a rag and to grease the commutator through this rag. If the lubricant is applied direct to the commutator surface, it should be properly distributed by wiping with a clean rag. In any case the lubrication should be done with the machine running and, as far as possible, with the power supply shut off.

Any liquid agents should be avoided.

If the chattering of the brushes can not be remedied by this means, it is recommended to try another type of brushes.

Cleaning

After grinding the brushes, clean the brush holders from brush dust during standstill of the machine.

Remove the brushes, blow the dust out of the brush guides with dry compressed air (max. pressure 5 kp/cm^2), vacuum cleaner or a pair of hand bellows respectively and remove the dust from the commutator space by means of a

vacuum cleaner (with a plastic nozzle). Any dirt sticking to brush holders should be removed by means of a not unravelling rag or with a brush. No cleaning wool or metal parts are to be used.

After a considerable operating time clean the whole brush supporting apparatus including all brush holders etc. The cleaning should be done in regular time intervals, depending on the operating conditions, during standstill of the machine. Especially brush supports and brush holders lying in the cooling air current should be checked for the accumulation of foreign bodies and dust.

Remove the brushes from the holders (eventually let the flex stay connected to the brush holder terminals) and clean the brush guides with dry compressed air, vacuum cleaner or if necessary with a pair of hand bellows. The pressure of the compressed air should not exceed 5 kp/cm^2.

Attention! Take care not to damage the brushes (breaking of the edges due to striking of the brushes when moved by the compressed air current).

Remove the dust in the commutator or slipring space with the aid of a vacuum cleaner (with plastic nozzle) or with a pair of hand bellows. The cleaning is especially necessary after grinding of the brushes and after skimming of the commutator or slipring.

Dirt sticking to the brush holders should be removed by means of a not unravelling rag or a brush. Use no cleaning wool or metal parts. If in special cases it is found necessary to use trichlorethylene or benzine for cleaning, protect the sliding surface with a strip of pressboard or similar material. Take care that no mixture of dust and trichlorethylene is formed during cleaning, which later on may be sucked into the machine. Therefore use benzine or trichlorethylene only sparingly. Take special care that no cleaning fluid is left standing in the spring casing of the brush holder.

Checking

Check the brush supports and brush holders carefully in regular time intervals, depending on the operating conditions, for tightness of all connections (cable lugs, tight seat of the clamping devices etc.).

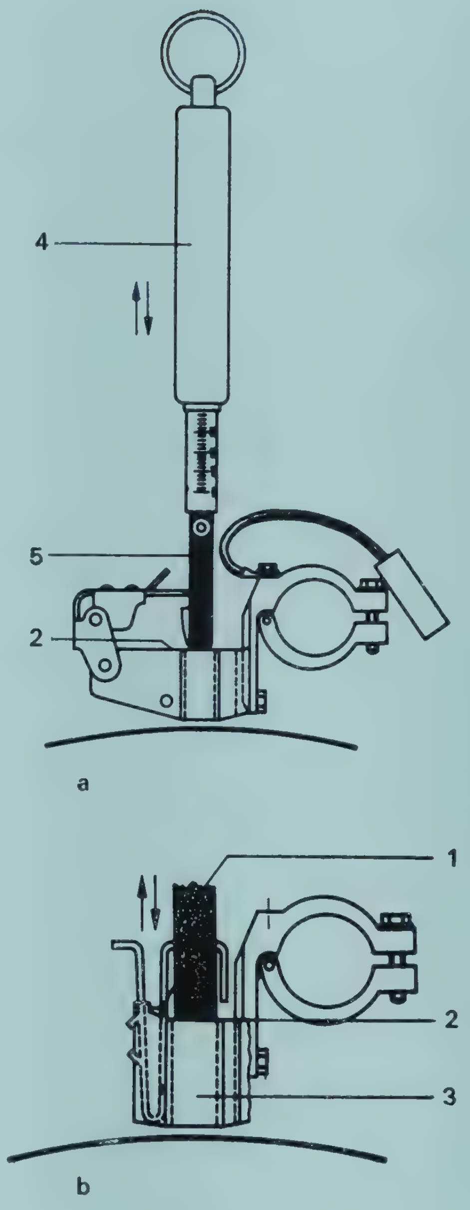
Check whether the joints or the insulating sleeves of the brush holders can move freely without being worn out.

Following a flashover it is necessary to make an especially careful check of the brush holders, brushes, sliprings or commutators.

Measuring the Specific Pressure of Brushes

The pressure must correspond to the special conditions, i.e. the type and application of the machine as well as the material and cross section of the brushes. Uniform brush pressure is a determining factor for a uniform current distribution between the individual brushes.

If a brush holder has been damaged by a flashover, a check of the brush pressure is to be made with the machine at standstill as follows. The check should be made as carefully as possible. Two persons are always necessary for making this check (one for the observation of the proper position of the pressure finger and one for the reading of the spring scale).



1 Leather loop
2 Upper edge of the brush guide
3 Roll spring holder
4 Spring scale
5 Leather loop

Fig. 1a and 1b Proper arrangement of a spring scale for measuring the brush pressure

A spring scale has proved best suited for checking the brush pressure of an installed brush holder. Spring scales are manufactured for various measuring ranges (up to 500 g, 1000 g and 2500 g).

Remove the brush. For checking the brush pressure fit the leather loop of the spring scale around the outermost working edge of the pressure finger or fit it around the plastic roll of roll spring holders, Figure 1b.

Attention: do not fix the spring scale to any holes provided in the pressure finger. These holes are only provided for pulling the pressure finger back with the aid of a hook, if the noses of the fingers can not be gripped tightly by hand.

Grip the spring scale at the ring and pull in the direction of the brush center line (do not tilt the spring scale) until the pressure finger is raised somewhat above the upper edge of the brush guide. Read the brush pressure off the spring scale and make a note of the reading, Figure 1.

A more exact determination of the brush pressure (under elimination of the joint friction) can be effected by lowering the pressure finger by means of the spring scale slowly until the pressure finger is again in a position slightly above the upper edge of the brush guide.

Determine now the mean value from these two readings.

The specific brush pressure (referred to the cross section of the brush) is determined as follows:

$$\frac{\text{measured brush pressure (mean value) in (p)}}{\text{cross section of the brush in (cm}^2\text{)}}$$

$$= \text{specific brush pressure} \quad (\text{p/cm}^2)$$

Brush springs which have aged or which are damaged by flashovers should be replaced by new springs of the same quality. The brush pressure should be uniform in all brush holders (tolerance ±50%). Unequal brush pressure may cause varying wear and temperature rise of the brushes as well as sparking.

An exception to this rule can be found where great metal graphite brushes are used. On this occasion the brush pressure on different studs can be different because of the position of installation (up or down). Occasionally even brush holders with different brush pressures are used in such cases.

After the grinding or skimming of the commutator or slipring miscellaneous, the radial clearance between the brush holder box and the surface has to be readjusted.

In case of a change in the direction of rotation of the machine it is necessary to remove light sheet-metal holders and inclined holders with 30° inclination and re-fit them according to the new direction of rotation so that the conditions laid down in the instruction MS 131 are fulfilled, i.e. the commutator bars should run the brush stud towards the brush. Cast holders on the contrary may be left in position. Check the vertical or inclined position. Axial displacement and tangential staggering should be adjusted and checked just in reversed order. Eventually the axial displacement should be marked on the brush stud with a pencil line.

Take care that the connecting cables for the brush rocker are still long enough for the new adjustment.

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Siemens Circuit

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July 1975

Contents

INSTRUMENTATION FOR CEMENT PLANT IN IRAQ

—P. R. TONSEKER

In the past, the control of technological processes in the production of cement relied mainly on the experience of operators. It was even believed for many years that automatic control of rotary kiln operation would not be possible. Systematic tests in recent years have changed the situation. The process variables were investigated theoretically and practically and it was found that many of the measured values, considered important in hand operation, were insignificant and could be replaced by other values which were recognised as more important. It was also found that if deviations from the desired values occurred at any given point of the production process, it was advisable, also, to readjust other set points slightly for rapid stabilization. In such cases two or more control systems need to be connected to form 'ratio' or 'cascade' control. A good knowledge of the process variables with special reference to sources of disturbance is, therefore, very important while planning an automation system.

The instrumentation scheme described here was designed for a 700 TPD cement plant installed at Iraq. Standardised systems have been introduced in this scheme wherever possible. Such systems make the task of the maintenance staff easier and simplify the stocking of spares as they permit interconnection of standard indicating instruments, recorders and other receiving instruments. This is done by means of transducers which have standard output signals of 0-20 mA DC. Transducers are devices which convert different process variable signals like pressure, temperature, flow etc. into standard electrical output signals. They are manufactured by Siemens AG, West Germany, under the trade name of TELEPERM. The output current of 0-20 mA DC is a function of the measured value and within wide limits is independent of the load, i.e. the number and resistances of the instruments connected. In cases where only indication of the measured process variable is required the primary elements considered have been relatively of the simpler type like thermocouples for temperature measurements, mechanical gauges for draft or pressure, tacho-generators for speed etc.

The choice of a suitable control system depends on the process conditions. Hence, as mentioned earlier, a thorough knowledge of the process variables is essential while designing a control system.

Automation Requires

(1) Proportionating devices capable of completely uniform feed in continuous operations.

(2) Sensitive proportionating devices suitable for control.

(3) Transmission without play of servo motors.

(4) Sufficiently high switching frequencies of servo motors and associated contactors.

(5) Sturdy construction and satisfactory installation of the control equipment.

The kiln is the heart of the cement plant. It is here that the sintering and chemical conversions take place under the effect of high temperatures. This section of the plant, therefore, needs particular attention and hence more measuring and control loops have been introduced here, as shown in Figure 1.

Kiln Hood Draft Control

The pressure at the kiln outlet or kiln hood does not seriously influence the calcination process directly as the quality of clinker is not affected by change in pressure conditions. It has, however, considerable side effects. If this pressure exceeds the atmospheric pressure, air will escape through joints between the rotating kiln and the stationary parts. The slight loss of heat is not as damaging as the large amount of dust which soon settles outside over a wide area with unpleasant side effects.

If, however, a heavy draft is created, cold air from outside will be sucked through the gaps which will lower the temperature in the kiln and adversely affect the burning process and its efficiency. Hence it is essential that a slight amount of over pressure of about +2 mm WG is maintained in this zone. This is brought about by regulating the position of a damper in an auxiliary chimney known as the cooler stack vent through which a small percentage of air is discharged.

If certain variations of the pressure at the kiln outlet from the desired value are tolerated a simple P action controller would be sufficient. A PI controller is, however, preferred as residual deviations are quickly eliminated due to the additional integral action. The TELEPERM Controller S 144 x 72 has been used for this application. It is an electric step controller

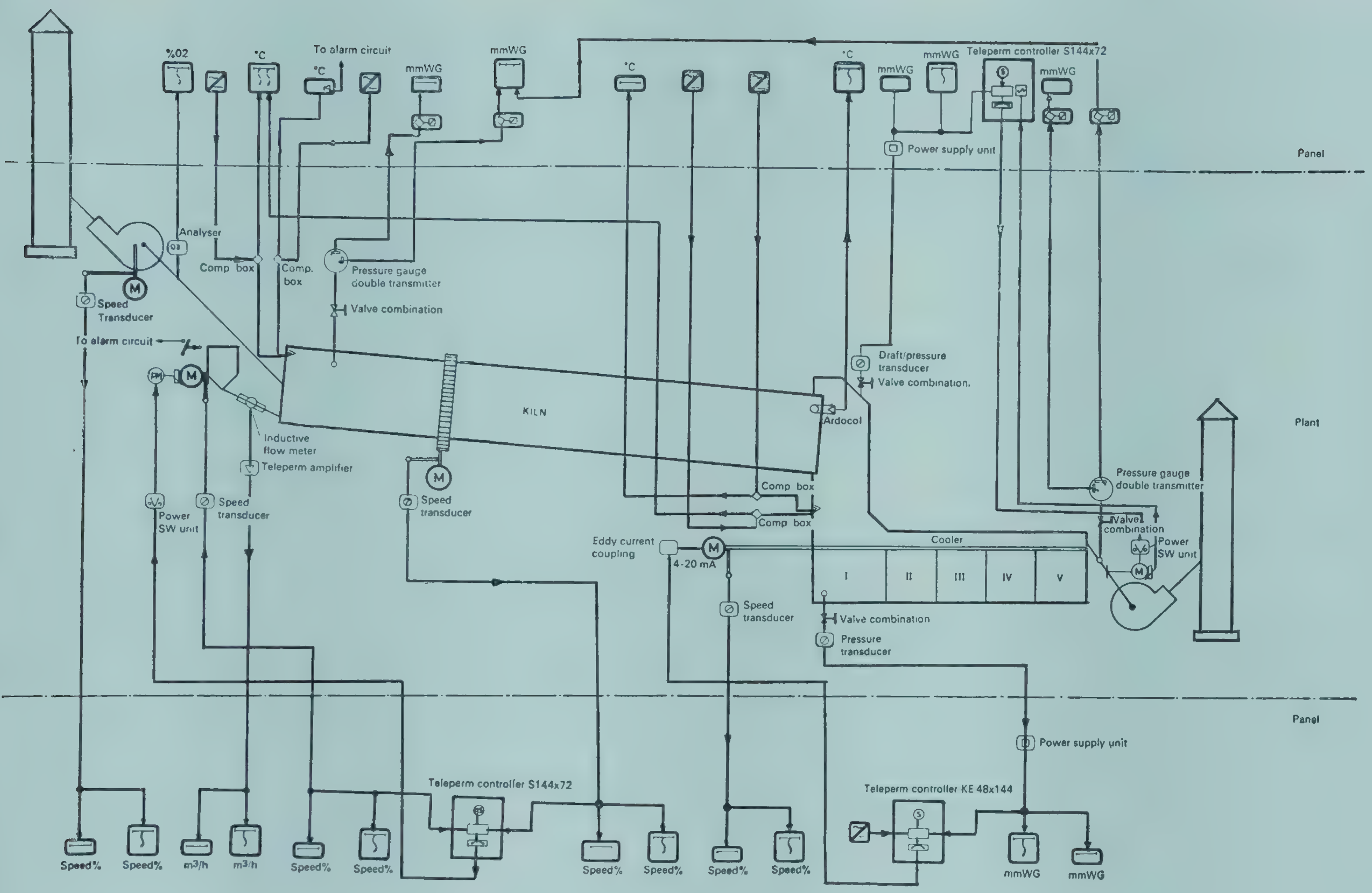


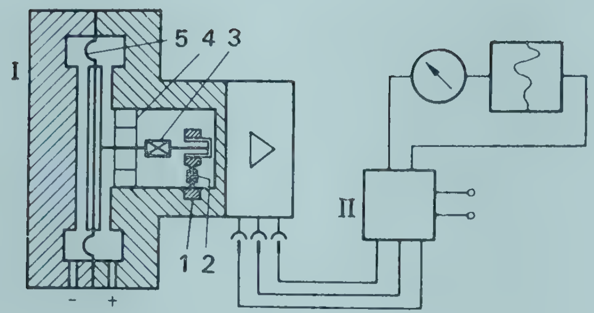
Fig. 1 Schematic Diagram of Measuring and Control Loops for Kiln and Cooler Section

which assumes PI action when used with an integrating actuator. For process variables like pressure, flow, etc. which have a tendency to assume different values in short durations, controllers with short time feed back are used.

A TELEPERM transducer with range (–) 10 to 0 to (+) 10mm WG senses the pressure/draft condition in the kiln hood. This transducer type M918 works on the strain gauge principle. Please refer to Figure 2, which gives a schematic arrangement of the transducer. The corresponding output of 0-20 mA DC is fed to the TELEPERM Controller. Depending on the amount and direction of deviation from the desired value of pressure, a series of pulses are generated by energising either one of the forward or reverse relays. The final control element is an electrical reversible geared motor which regulates the position of the damper in the cooler stack vent. As mentioned earlier such control applications require high switching frequencies of the geared motors alongwith the associated contactors upto a 1000 switching operations per hour. Further, the gearing unit should have as little back lash as possible. In the KE6 actuator used for this purpose, planetary gear systems are used ensuring that transmission of torque and speed is brought about with the minimum of back lash. Further, the regulating gears developed for the purpose have much closer manufacturing tolerances than generally customary.

Control of Undergrate First Compartment Pressure

On leaving the rotary kiln, the clinker is cooled, as rapid cooling improves the quality of cement and at the same time the valuable heat content of the clinker is reclaimed. Grate coolers permit good reclamation of heat which benefits the entire heating system. The clinker is cooled to a temperatures below 100°C and this cooling is brought about by forcing in air from below the grate, causing the clinker to give up



I Transducer
II Power supply or square-root extractor
1 Bending spring
2 Strain gauges
3 Force limiter
4 Parallel guide
5 Diaphragm with plate

Fig. 2 TELEPERM Transducer M918 with Strain Gauges

its heat content. The heated air known as the secondary air is drawn into the kiln for further utilisation. The air from below the grate is forced by means of blowers separated by a series of compartments.

For proper kiln operation, the waste gas flow must remain reasonably constant. Since the flow of primary air is practically constant, it is essential that the flow of air passing through the grate must also remain constant. If, however, due to some disturbing factors, the grate resistance increases, counter pressures will build up impeding the flow of secondary air. This flow can again be brought to the same level by regulating the cooler grate speed. Thus keeping the undergrate pressure constant, by regulating the grate speed, the flow of secondary air can be controlled. It is sufficient to control the pressure only in compartment I.

A TELEPERM Pressure Transducer converts the pressure signals (normally in the range of 0-250 mm. WG) into a load independent current of 0–20 mA DC. The speed of the cooler grate is regulated by means of an eddy current coupling device. The controlling current supplied to this is 4–20 mA DC from a TELEPERM KE controller. This controller with PID action, has a continuous output of 4–20 mA DC corresponding to the actual value signal received from the transducer. The actual value generates a voltage in the comparator unit of the controller. The voltage tapped at the set point adjuster and the actual value are fed to a series of amplifiers including a PID feed back amplifier unit. Finally an output amplifier generates the controlling current of 4–20 mA DC corresponding to the input signal and set point value fixed.

Scoop Wheel Speed Control

One of the important requirements in kiln operation is to keep the degree of filling of the rotary kiln constant and to change it only gradually in the case of a change of operation. One of the best methods of achieving this is to regulate the scoop wheel speed in relation to the kiln speed. This is a very logical method as the degree of filling might become excessive if the scoop wheel rotates too fast and the kiln too slow, or too small in the opposite case.

In this control loop the speeds of the scoop wheel and kiln are synchronized by keeping their ratio constant. The TELEPERM S controller with PI feed back is used for this purpose. TELEPERM speed transducers convert speed signals from the kiln and scoop wheel drives to an impressed current of 0–20 mA DC. The step output of the controller operates a pilot motor which regulates the speed of the scoop wheel.

Gas Analysis

The continuous analysis of the waste gas is of prime importance in effecting the proper regulation of the calcination process and in reducing the energy consumption.

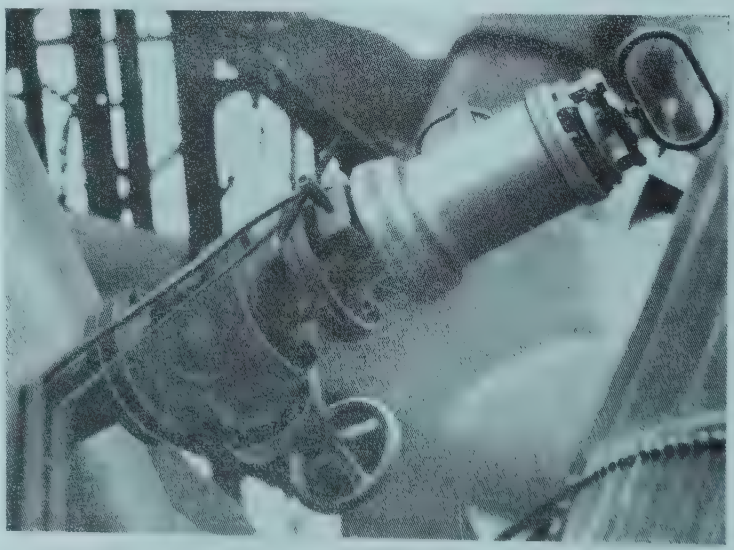


Fig. 3 Gas Sampling Device with Electrically Heated Filter

Theoretically, the O_2 content of the flue gas should be zero for ideal combustion. This cannot be achieved as such an intimate mixture of fuel and air is not possible. Hence, some excess air is invariably used. The ratio of air actually required to theoretical amount of air is different for different fuels used. The oxygen contained in the excess air passes into the flue gases. By heating a small quantity of excess air not used for combustion, the loss of energy is smaller than that resulting from unburnt carbon or carbon monoxide. Lack of air causes incomplete combustion resulting in formation of carbon-monoxide.

$$C + \tfrac{1}{2}O_2 = CO \quad \text{or} \quad C + CO_2 = 2CO$$

A theoretical air deficiency of 10% reduces the efficiency by about 8% at 300°C waste gas temperature while an excess air of 10% reduces the efficiency only by about 1%. Hence it is important to know

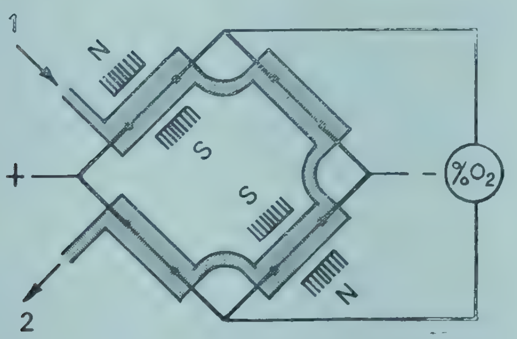
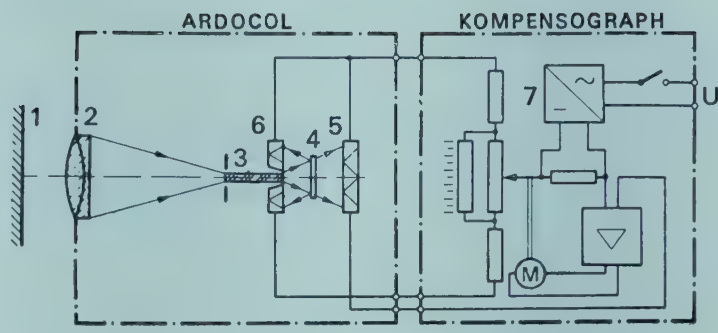


Fig. 4 Gas Flow and Circuit Diagram of OXYMAT

the amount of oxygen in the waste gases for adjusting the air/fuel ratio. In fact, for practical regulation, analysis of the oxygen content in the waste gas is all that is required.

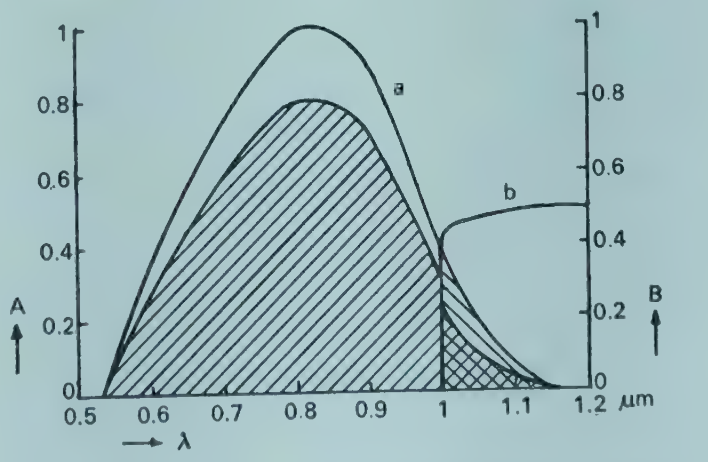
The gas extraction device is the first link in the chain of a series of instruments. Sampling of gases is a very complicated process in cement kilns. The probe varying from a length of 1500 mm to 3000 mm is inserted in the thick lining of the dust chamber before it reaches the gas space. Depending on the dust content, moisture content, temperature and other conditions of the gas, different types of extraction devices are used.



1 Lens system
2 Radiator
3 Light-directing rod
4 Indium-phosphide (InP) filter
5 Silicon photocell
6 Silicon photocell
7 Kompensograph

Fig. 5 Measuring Principle of ARDOCOL

In this particular process the temperature of the gases where the sample probe is inserted varies from about 150°C to 300°C and the moisture content of the gases is also sufficiently high. Considering these various factors, a gas sampling probe with an electrically heated glass wool filter, has been used, Figure 3. This ensures proper removal of the coarse dust without condensation. Diaphragm filters are used for removal of the fine dust. A diaphragm pump is



A Relative sensitivity
B Relative transparency
a Relative sensitivity of silicon photocells
b Relative transparency of the InP filters

▨ Relative sensitivity of silicon photocells to the radiation reflected by the InP filter
▩ Relative sensitivity of silicon photocells to the radiation transmitted through the InP filter

Fig. 6 Spectral Sensitivity of Silicon Photocells and Spectral Transparency of InP Filters

used as a suction device for transporting the gas to the analyser proper.

Oxygen is practically the only industrial gas which is paramagnetic. This property of 0_2 is used for gas analysis in the OXYMAT analyser. Figure 4 explains the working principle of the OXYMAT. The poles of a permanent magnet extend into a test cell of a non-magnetic material. A platinum resistance wire which is electrically heated to approximately 300°C is mounted within the zone of maximum field strength. The magnet at first exerts a strong attraction upon the 0_2 present. As the 0_2 is heated, it loses a part of its paramagnetism and is replaced by colder and more 0_2. The resultant gas circulation cools the platinum and causes an additional variation of its resistance. By means of a wheatstone bridge the four arms of which are each located in a separate cell, the 0_2 analysis is reduced to a resistance measurement. A dotted line recorder calibrated for a range of 0–10% 0^2 is used to record the 0_2 content in the flue gases.

Sintering Zone Temperature

The temperature in the sintering zone is one of the most important measured quantities for kiln operation. It is the ultimate criterion of correct burning. In the case of the hand controlled rotary kilns, the kiln foreman checks the charge periodically. However, this objective evaluation of temperature is very approximate. By making use of suitable instruments, this temperature can be continuously monitored. The ARDOCOL radiation pyrometer is widely used in the measurement of temperature for such applications. Figure 5 describes the measuring principle of ARDOCOL. It is a two colour radiation pyrometer which determines the temperature of a body from the ratio of the radiation intensities at two wave lengths. This enables an error free measurement independent of the emissivity of the object, provided the same emissivity exists at both wave lengths. Si photocells serve as radiation receivers. Through an indium-phosphide (InP) filter, which lets pass a part of the radiation above 1 μm, the radiation falls on one of the Si photocells. The radiation below 1 μm is reflected by the filter and falls on the other Si photocell. Corresponding to the impinging radiation intensity, the Si photocells generate D.C. voltages, the ratio of which is a measure of the temperature. The spectral sensitivity of silicon photocells and spectral transparency of InP filters is shown in Figure 6. A potentiometric recorder KOMPENSOGRAPH records the actual value of the temperature accurately.

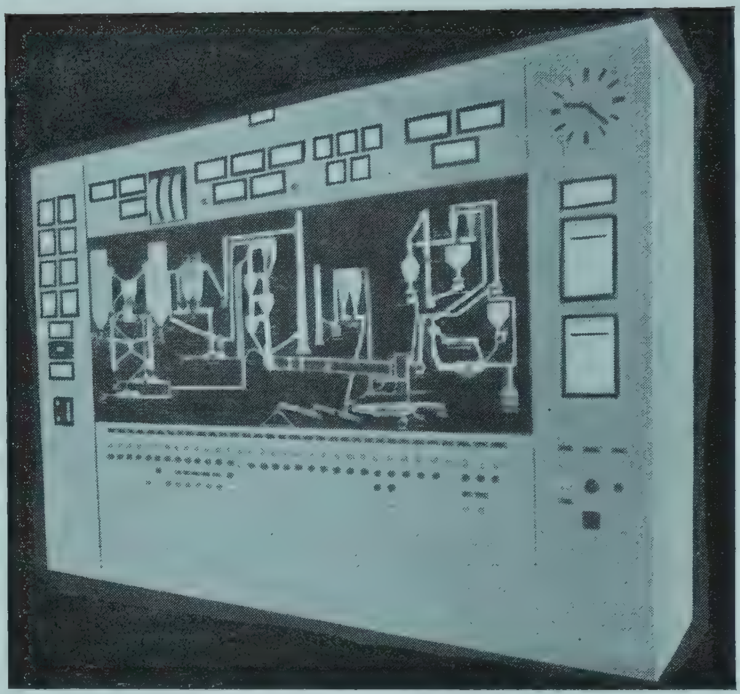


Fig. 7 Control Panel for Kiln and Cooler Section

Control Panels

From the convenience point of view all data concerning the production process are fed into individual control panels, preferably kept in a single control room. It is from here that the production is controlled and monitored. An exact replica of the particular plant section is provided on the control panel in the form of a painted mimic. Miniature lamps on the mimic indicate running condition of various drives and also level conditions in storage bins and silos. Figure 7 shows a Kiln Control Panel.

The entire system for instrumentation and control also includes the alarm circuitry for the transmission of the signals, if the measured data is exceeded or not reached. In order to ensure that congestion of material and resultant breakdowns do not occur, the starters of the various drive motors are interlocked in a sequential phase opposite to the flow direction.

NO BREAK SET FOR THE CONTINUOUS PROCESS INDUSTRIES

—S. L. AGARWAL

In some industries, where the process is not interrelated, and units can function independently, it may be possible to allow interruption of the main power supply, but this will not be possible for the continuous running plants where the main power supply can cause loss of production at various stages, resulting in a complete loss for this period for the final product. For nylon fibre, polyester, rayon and other such plants it may not be economical even to allow interruption to the supply of the control system.

Industries

The power break-downs are mainly as follows :

1. Voltage dip in the system (momentary interruption).
2. Main power supply interruption for a short period.
3. Main power supply interruption for a longer time.

The constant voltage generator sets, synchronous or induction type, can be used for uninterrupted, power and control supply. The synchronous generator upto 1500 kVA and induction generator upto 700 kVA, have been supplied by our Principals, Siemens AG.

The emergency non-interrupted power supply can be derived by diesel generator sets coupled with constant voltage MG sets and flywheel unit. Figure No. 1 shows block diagram of system. Under normal conditions when power supply is available from the main network, the electric motor supplies power to drive the flywheel and the generator. During a failure of the voltage, the electric motor is disconnected from the supply mains network, the electromagnetic clutch is energised and the diesel prime-mover starts automatically and is immediately pulled to its rated rpm (speed). The flywheel drives the generator for 1 to 2 seconds. After this time interval, the diesel prime-mover attains its speed and drives the generator, feeding the uninterrupted supply to the system. In case of the main supply restoration, the electric motor is switched over to the supply main after a pre-determined time. The excitation of the electro-magnetic clutch is disconnected and the diesel set closes down.

The uninterrupted control supply can also be achieved by providing a suitable R. C. Circuit in the individual motor control circuit. With a suitable design of rectifier, capacitors and resistance it is possible to attain the opening delay upto 5 seconds. (See Figure 2.) The contactor holds on reliably even if the coil voltage drops down to 45% of the rated value.

This will have the following disadvantages

1. Each feeder will require a contactor with built-in R. C. Circuit, which will require more space in the MCC, which in turn increases the number of panels and length of MCC (Motor Control Centre).

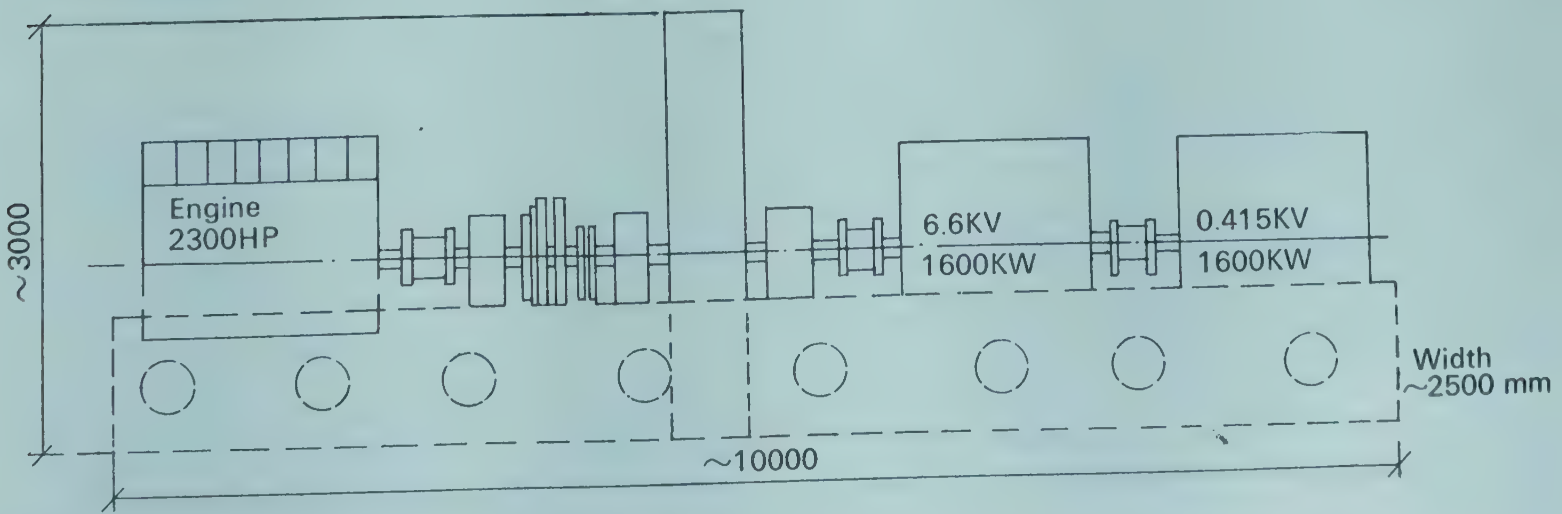


Fig. 1 Block Diagram for No Break Diesel Generator Set

2. The cost of additional individual units will be uneconomical.

3. Due to malfunctioning or break of single contactor unit with R. C. Circuit, the process will be interrupted. Hence absolute reliability cannot be achieved.

The article deals in details about the uninterrupted supply, through 10 kVA flywheel generator, for the control circuitory.

Construction

The motor and the alternator are mounted on a combined base plate, which is grouted into the foundation at the site. Division of the flywheel masses will depend on the permissible bearing load of the motor and the generator.

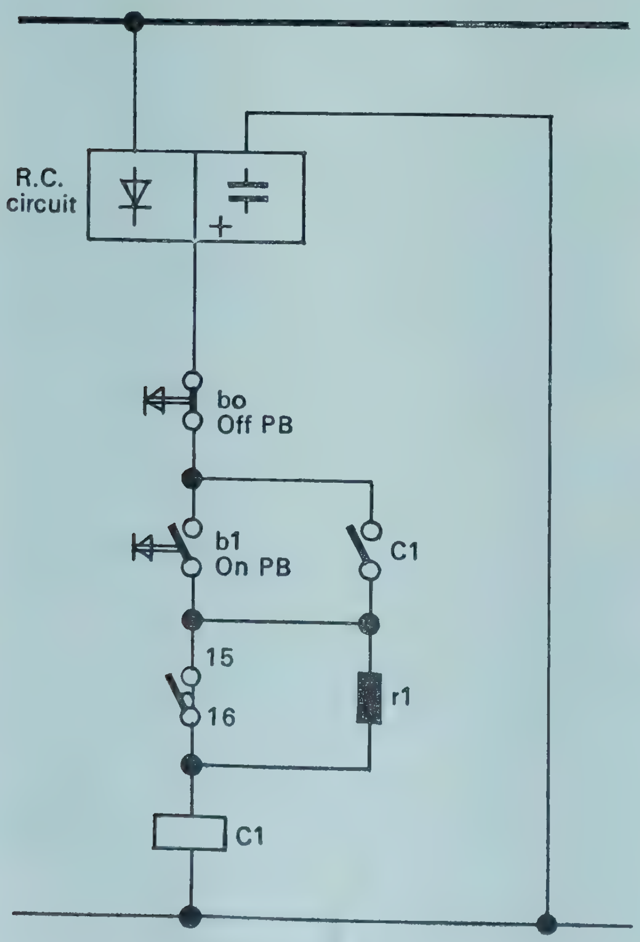


Fig. 2 Contactor with R. C. Circuit

Fig. 4 shows mounting, front view, side view of the 10 kVA flywheel generator set. The approximate overall dimensions are length 1330 mm, depth 630 mm, height 725 mm; the weight of the unit is only 600 kg. approximately.

Control Schematic

Figure 3 shows a schematic diagram with a 30 outgoing circuit. The control cubicle incorporates a constant voltage unit, which is separately supplied and which can be mounted near the set, depending upon the suitability of the place. The only special equipment required is a constant voltage unit and time relay.

From the control schematic it is clear that the motor is continuously driving the generator, which is feeding the control supply continuously to the control system of the circuits.

In case the supply voltage of the mains fails, due to a voltage dip in the system, the flywheel which has stored the energy, will allow the generator set to run for 3 seconds or 8 seconds depending upon the time required and on the flywheel design. This will ensure that the control circuits are fed with continuous supply, despite the voltage dip, and also that the contactors will not drop out. As soon as the dip is over and the supply is restored, all the motors will run at a full speed.

This will ensure a considerable reduction of the time break in production, which is particularly important in a continuous process plant such as nylon or polyester, where the voltage dip can cause a loss to the tune of one lac of rupees (15 tonne capacity plant).

Figure 5 shows the front view, without door of the control panel of 10 kVA flywheel generator sets. The details show arrangement of various equipment inside the control panel.

A voltage dip lasts for 2 to 3 cycles i.e. 1/20 seconds which can be due to a fault in a 22 kV or 33 kV HT grid. For such a small duration, the OLTC with automatic relay, will be unable to sense the dip and the contactor control voltage may fall to less than 50%, causing the contactors to drop out. Once the contactors have dropped they have to be restarted by the operator, which causes a break in the yarn,

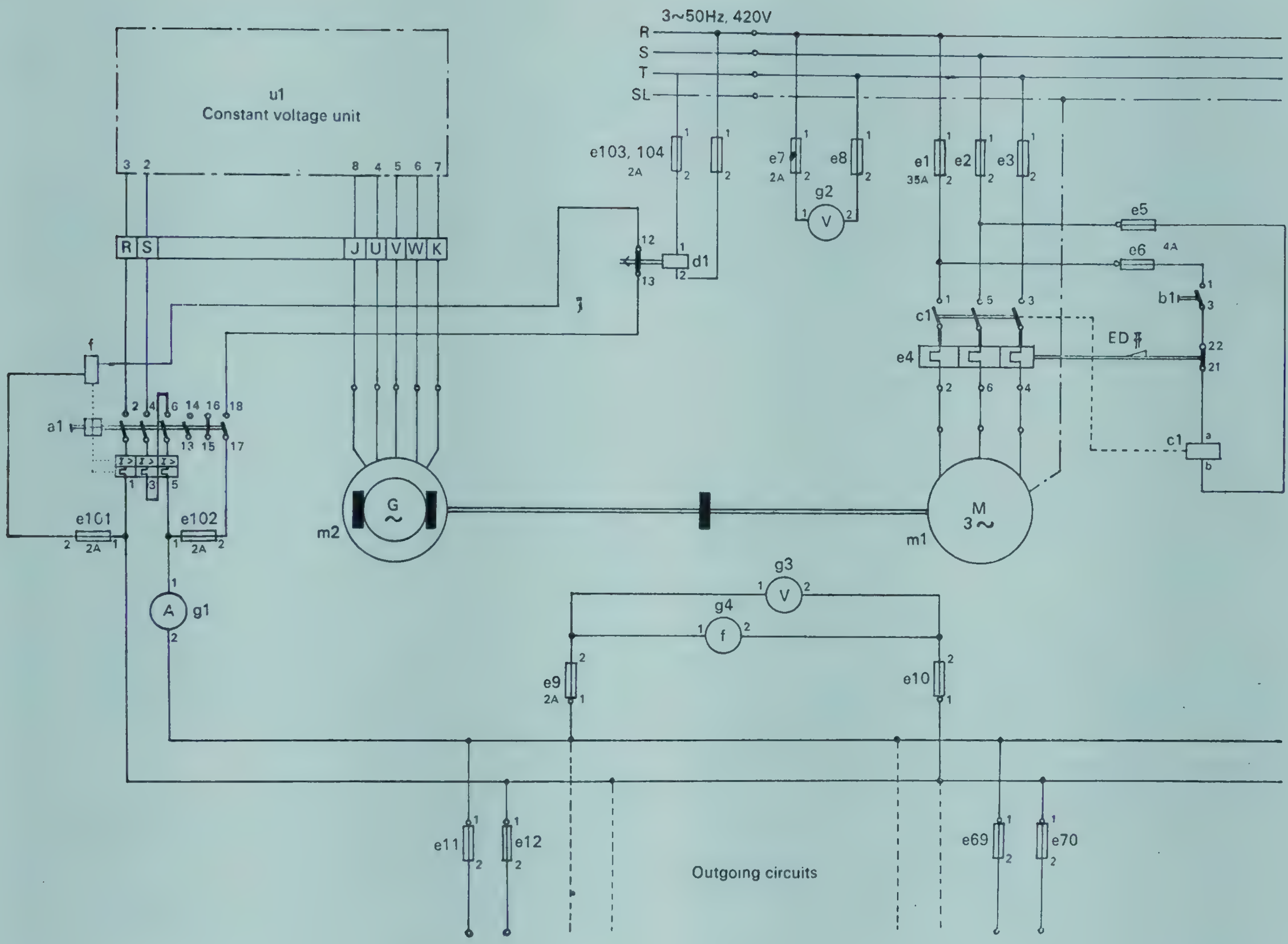


Fig. 3 Flywheel Drawing

resulting in sub-standard bobbins in a synthetic plant. Moreover, it will also result in loss of time and production.

For polyester or nylon plants in particular sections, such as the extruder, take up spinning and draw twister section, it is essential to feed the control circuit through the flywheel generator, to take care of the voltage dip.

Parallel Operation of two Motor Generator Sets

To achieve absolute operational security of an installation, the sets can be connected in parallel. They are fed from separate supplies. Should the supply of one fail, the second alternator will take over the full load and the first will work as a motor with no load. In case the supply is restored in normal time the alternator output will return to normal. Also, during overhaul, one set can be utilised for continuous operation. It is also possible to supply the two sets in such a way that one is a standby while the other is normally in operation.

Application to Data Processing Plant

For a data processing plant, a current at constant voltage and frequency is desired. Data processing plants are normally supplied by the synchronous alternator. The DC motor is fed from the main via a silicon rectifier. The load dependent excitation system ensures a constant alternator voltage. The

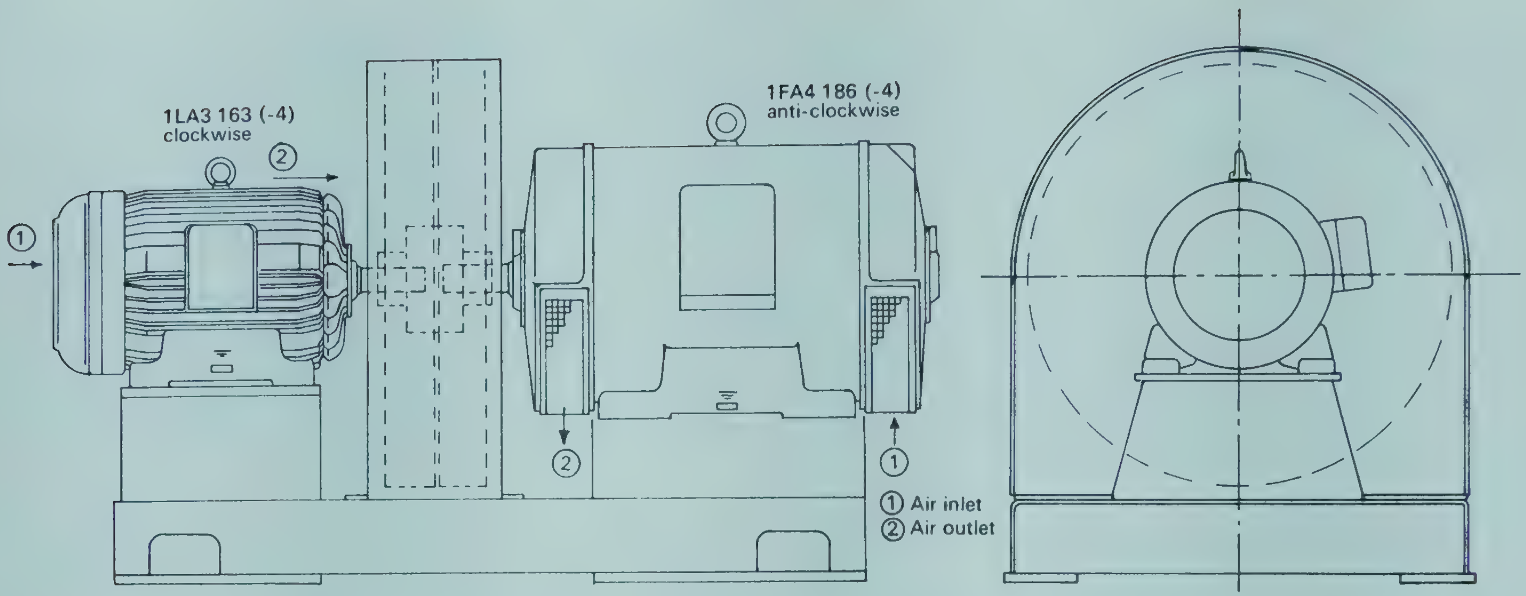


Fig. 4 Flywheel Motor-Generator set

frequency is maintained by feeding the shunt field of the DC motor, through a transistorised regulator with an installation incorporating a battery, which ensures a stable speed, independent of the fluctuation of a system voltage and the load on the motor-generator set. This is permanently connected on the output side of the main rectifier and in the event of a main failure, it supplies the motor and avoids the necessity of changing over to an alternative source of supply. Figure 6 shows the single line diagram of the flywheel generator set for data processing plants.

Special Features of Flywheel Generator Set:

The features of Induction Motor and synchronous motor generator sets are given hereunder :-

A. Constant voltage induction motor generator sets:

1. Simple and robust construction (squirrel cage induction generator)
2. Suitable for use in hazardous area
3. No sliprings or brushes
4. No auxiliary supply source necessary
5. Not capable of carrying sustained short circuit current and highly sensitive for inductive shock loads.

B. Constant voltage synchronous motor generator set:

1. Insensitive to overload and sudden load change
2. Capable of carrying sustained short circuit currents
3. Selective tripping of faulty control circuit
4. Excellent voltage control between no load and full load
5. Adjustment of the excitation equipment at site not required
6. No auxiliary supply source necessary
7. Automatic synchronising with parallel operation.

No break generating sets can also be used for :

1. Radar Stations with and without electronics data processing.
2. Radio Stations.

3. Signalling and control system for the rail transport.

4. Supplies to the important stations—auxiliaries for the conventional and nuclear power stations.

The initial cost of the no break set is relatively high; the running cost, except for the synchronous motor generator sets are also high. One has to plan the requirements carefully considering the fixed and running costs of the set, in comparison with the returns obtained due to non-interrupted supplies. From experience we find that for continuous process plants it is worthwhile investing in the no break sets. At present the no break sets are still to be produced indigenously. As a compromise one has to run the no break set, by running the automatic starting diesel generating sets continuously, to feed the critical loads.

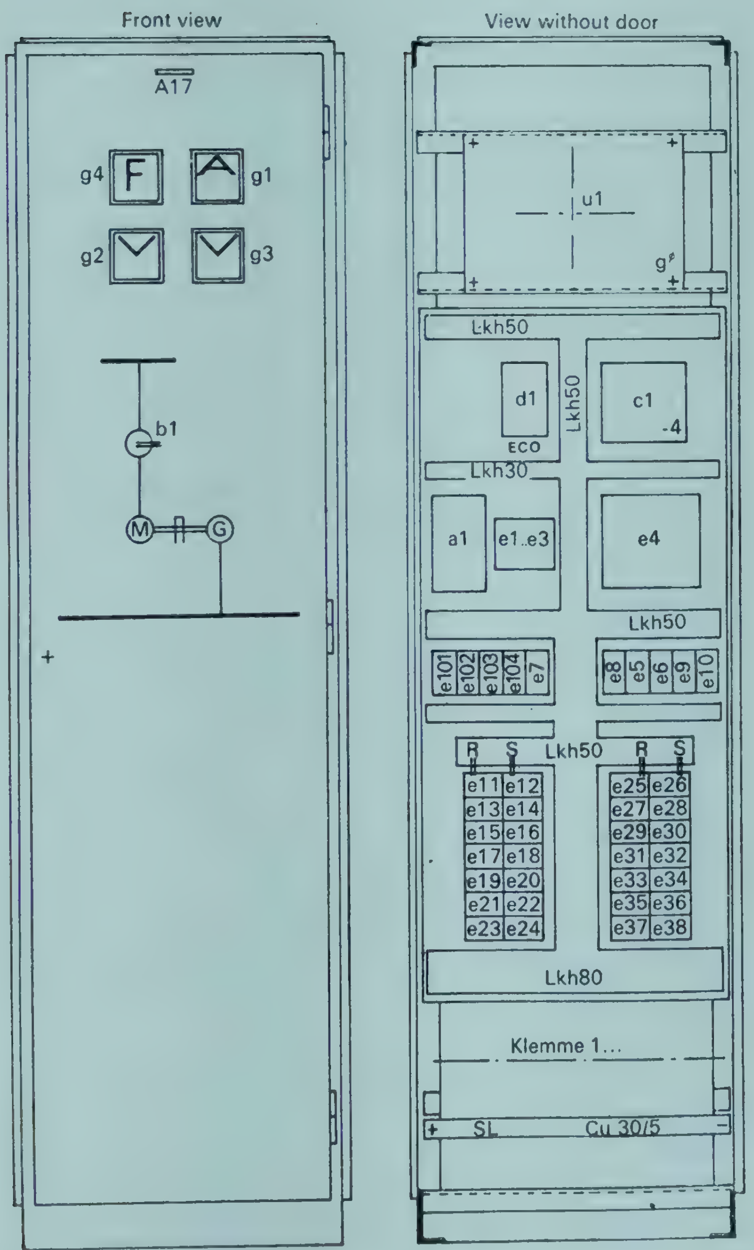


Fig. 5 Switchboard for 10 kVA Generator

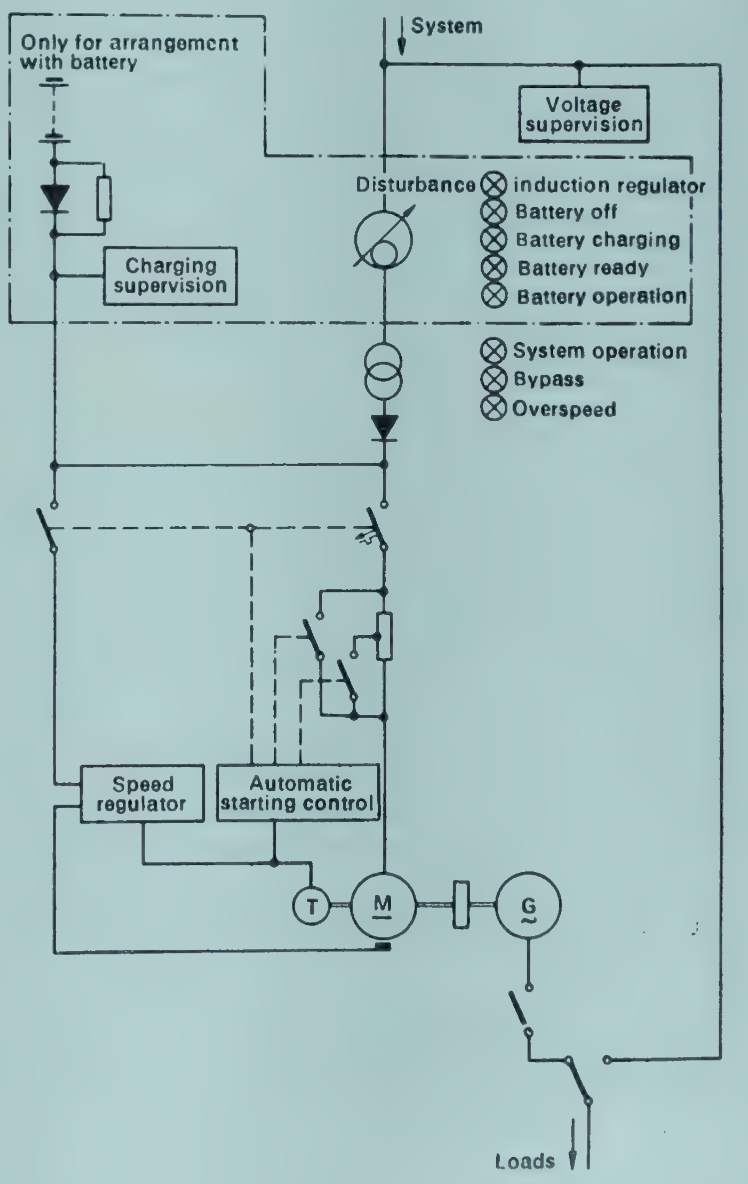


Fig. 6 Flywheel, Motor Generator Set for Data Processing Plants

ELECTRICAL EQUIPMENT FOR PAPER PLANTS

—S. LAHIRI

When paper was invented about 2000 years ago in China, no one could imagine that the per capita paper production of a country, would, one day be an index for determining the progress of the country. About a decade ago, the world average of annual per capita consumption of paper was approx. 30 Kg. — corresponding to only 1.5 Kg. for India. This clearly indicates the advancement necessary in this field if India is to come anywhere near the world average.

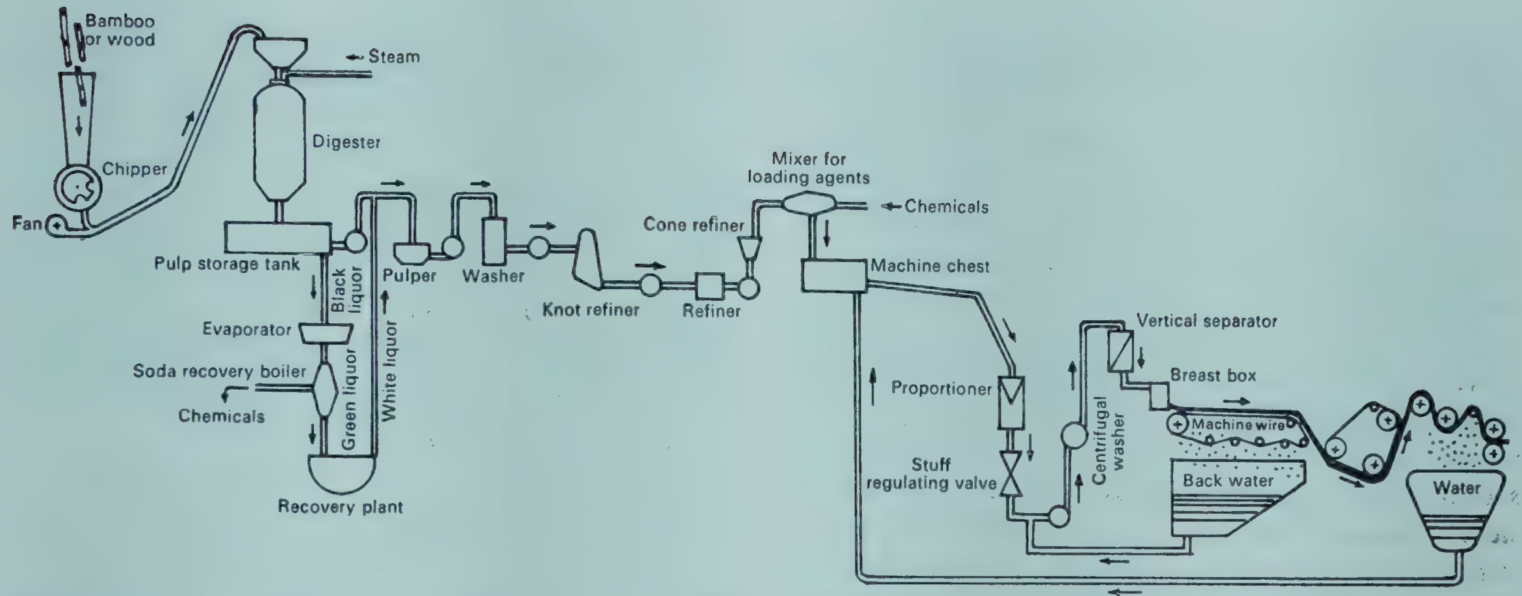
This necessity has already been identified by the Government and all efforts are being made to mobilise resources to bridge this gap. But the job is not easy, since the paper industry is essentially capital intensive and requires large investments, which only a few large industrial houses and the Government can afford. Due to this, the growth in this field is not up to expectation. The Government has termed this a 'priority industry' and has started setting up a few fairly large paper mills on an urgent basis. Some of the major existing mills are also trying to expand or trying to increase production by adopting advanced modern techniques. Some small paper mills using rag or waste paper as raw material are also coming up.

Paper industry and electric power are very closely associated. Highly efficient machines with increased production rates can only be designed with the incorporation of modern electrical equipment and advanced electrical control techniques. The power consumption in a paper mill is quite high. For instance, in a pulp and paper plant having a production capacity of 100 tons of finished paper per day, the power requirement may be approx. 1300 kW. The energy consumption per ton of paper may be between 600 and 1200 kWh. In order to utilise this large amount of electric power, a flexible, efficient and reliable power distribution system must be designed, keeping in view the special needs of the industry.

In order to appreciate the special electrical requirements of this industry, it will be helpful to have an idea of the process involved. For a paper mill, manufacturing, writing or kraft paper, using bamboo or wood as raw material, the basic processing is carried out in the chipper house, digestor, pulper, refiners, washing and screening sections and finally in the paper machine. Figure 1 indicates the processes involved together with the salient electrical requirements for each section. After the paper machine, the paper passes through calenders, coating plant, slitters, cross cutters and finally the packing section.

The solid raw material i.e. bamboo or wood is first cut into pieces in the chipper house and sent to the digestor. The transportation of the cut chips from chipper house to digestor is usually done through pipes in which a strong air current is produced by powerful ID fans. At the digestor, the chips are mixed with water and chemicals (caustic soda etc.) and heated by steam to a calculated temperature for a definite period. In this process the fibres separate out and the useless lignin is removed. The chemicals used in the digestor are partly recovered in the recovery plant and are used again. The chemicals being quite expensive, the amount of chemicals recovered in the recovery plant affect the costing of the paper directly. For newsprint, this process is usually avoided in order to reduce costs and the wood is ground at the initial stage by large wheels thereby separating the fibres mechanically. After this section the stock is passed through pulpers and refiners, where the clusters are broken by vertical action, or by turbulence, in order to make an uniform feed. After this, it is mixed with chemicals, bleached and washed before being pumped into the paper machine. In all these sections, the fibres remain in water as a mechanical mixture or suspension in water. Before entering the paper machine, the water content is approx. 98% by volume. This makes the material movement from section to section possible, by pipes and pumps. Another aspect evident from this fact is the necessity of a large amount of water for paper production. It may be considered that the water is also one of the major raw materials necessary for paper production. As such, a reliable water supply system must be ensured.

In the paper machine, dewatering of the stock takes place. First the stock enters the breast box, where the stock is spread uniformly over the width of the machine and is allowed to fall over a porous belt called the machine wire. As the stock moves with the wire, dewatering takes place and the sheet is formed. The dewatering action in this section is



Chipper	Digester	Pulper	Refiners	Washing & screening	Paper machine	←
Slipring or high starting torque sq. cage motor	Sq. cage motor	Sq. cage motor	Slipring on high starting torque sq. cage motor	Sq. cage motor	DC motor	Drive
TEFC IP 44	TEFC IP 55	TEFC IP 55	TEFC IP 44/IP 55	TEFC IP 44	SP/TEFC	Drive enclo.
Heavy duty cast iron or sheet steel enclosed	Heavy duty CI enclosed	Heavy duty CI or sheet steel enclosed	Heavy duty sheet steel enclosed	Heavy duty sheet steel enclosed	Heavy duty sheet steel enclosed	Switchgear
Const. speed Local/remote control	Const. speed Local/remote control	Const. speed Local/remote control	Const. speed Local/remote control	Const. speed Local/remote control	Variable speed. Ward-Leonard or thyristor control	Control
Dust proof	Acid/alkali proof paint	Acid/alkali proof paint	Acid/alkali proof paint	—	Very fine speed control. Control room separare. Thyristor room air-conditioned.	Special features

Fig. 1 Flow Diagram of Paper Pulp

aided by vacuum pumps. The paper sheet thus formed is passed over to felt belts which take it through the pressing section. Here the paper is pressed between rollers in order to reduce the water content. In this process about 50-60% water is removed. Further dewatering is not possible by mechanical pressure and, as such, the sheets go to the dryer section where they are passed through cylinders heated by steam.

It is evident that the speed of each roller/cylinder in the paper machine must be fully synchronised in order to obtain the same peripheral speed, otherwise the paper will either tear in-between the roller, or it will get crumpled and bunched up. Originally a paper machine used to be provided with one DC main drive motor and a line shaft for driving the individual cylinders. The speed of individual cylinders used to be adjusted by a cone pulley and belt shifting arrangement. In this process, speed adjustment is slow and tedious. Apart from this, the slipping of belts causes problems. In order to avoid this, some manufacturers use a differential gear box, connected with line shaft for driving individual cylinders. But in both these processes, the efficiency of the system goes down and speed control is not very quick. This problem can be overcome by sectional drives, which require the distribution of separate motors throughout the machine, to drive different cylinders. The speed of each motor is controlled accurately with the help of a tachogenerator mounted on each motor and an efficient speed controlling device, which controls the armature voltage, and the field of the DC motors. This control is done presently by two methods — Ward Leonard control and thyristor control. While the Ward Leonard method is quite reliable and has been in use for many years, it has certain disadvantages— such as the requirement of a large space and expensive machine foundation for the Ward Leonard set, necessity of regular maintenance, tendency to wear and tear, necessity of keeping many types of expensive spares, lower efficiency compared to thyristor and

slower response time. These disadvantages have been overcome with the thyristor control unit.

In a typical MG paper machine (machine glaze), drives may be divided in three principal sections i.e. wire section, MG cylinder section and reel section. Each of these sections may have more than one motor but their speeds are controlled from a common busbar. However, each motor is provided with an individual field control. A typical thyristor control system is shown in Figure 2. From the Figure, it may be seen that the speed of the main section motor is controlled directly, whereas the other motors of the section are connected in parallel. The control of speed of each section, is achieved with the help of a transistorised controller. In this controller, the actual value of speed obtained from a sensitive tacho-generator, mounted on the motor, is compared with a steady reference voltage. The controller, in turn, controls the thyristor which is the final controlling element.

A common reference voltage is given in all the three sections. The actual value of speed obtained from the three tacho-generators of each section is also obtained. The reference voltage and the values obtained from the tacho-generator are converted to matching units and compared in the speed controller. Also the actual value of current is obtained from a shunt in the main power circuit and connected to a current controller. This controller prevents abrupt variations in current, due to variation in voltage, and acts as a subordinate to the speed controller. The combined effect of the speed and current controllers, controls the gate of the thyristor, which ultimately controls the voltage/current of the motors for achieving the desired speed.

The above mentioned control ensures constant web tension with the presupposition that the stock consistency, pressure of rollers, temperature of dryers, will remain constant. In case these changes demand correction of the web tension, then the potentio meter in the reference voltage circuit has to be adjusted. Today newsprint machine have been developed with speed going upto about 900 metres per minute, while for machines producing tissue paper the speed goes upto approx. 1,200 metres per minute.

At the end of the paper machine, the paper is wound in a reeler, which reduces the RPM as the reeling goes

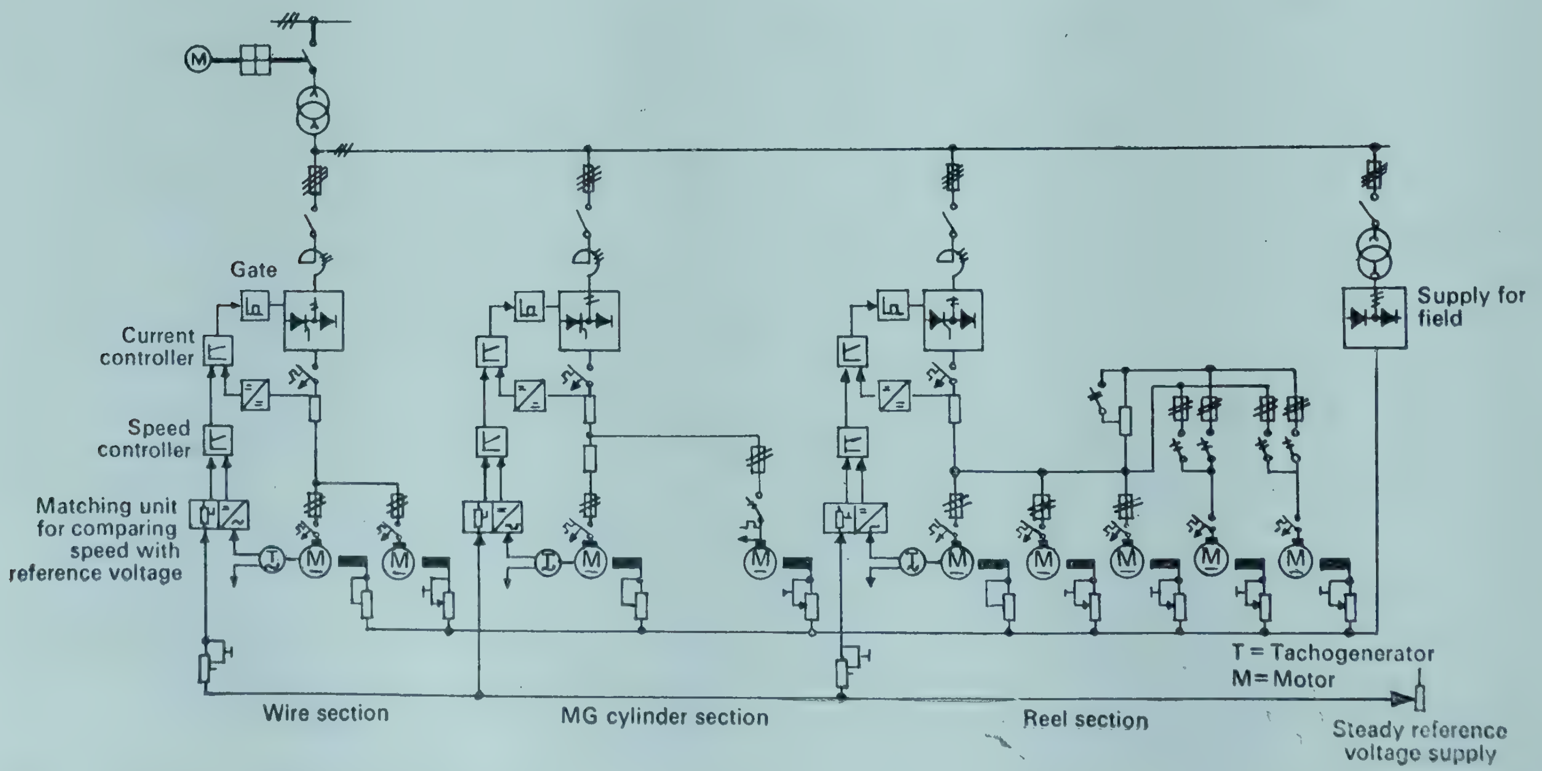


Fig. 2 Schematic Diagram of Sectional Drives

on, in order to maintain constant tension. This is usually done by the Pope reeler which is driven by another cylinder by friction.

Figure 3 gives the details. This method is possible for stronger papers but not for fine paper like tissue paper, which gets damaged by friction. In such cases the roll is driven directly by a DC motor, with a special control device to change the speed to accommodate change in diameter, keeping the power/current constant.

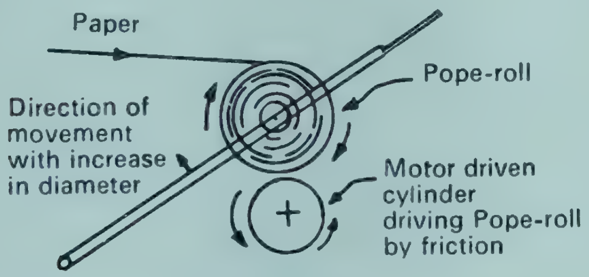


Fig. 3 Tensioning of Paper on Pope Roll

After the paper machine, the paper is passed on to the sizing and coating sections, in order to increase the resistance of the paper to water and to obtain a smoother denser surface, making it suitable for printing. After this, calendering is required. In the calender machine, the paper is passed through cylinders placed vertically on top of each other. The paper is pressed in between rollers not only by the weight of the rollers but also by additional pressure exerted hydraulically. First, the paper is threaded through the rolls of the machine by hand and the machine has to run at a very slow speed. It has to be ensured that there is no crease in the paper. After this the speed is increased. Since the calender operates intermittently the speed of the calender must be higher than the paper machine in order to cope with the production of the paper machine. Usually, it is 50% higher. In the calender machine, the bottom roller is driven by a motor, while the other rollers are driven by friction. The load on the driven motor is dependent on the pressure between the rolls and partly on the paper tension. Depending on the quality of the paper, the speed of the machine is fixed. In addition to this, the calender must be provided with a brake so that it comes to a halt quickly, on emergency stopping. The unwind roll is provided with a brake for maintaining uniform tension. This may be a mechanical brake or a braking generator. The wind roll may have a similar arrangement of a pope wheel, described above. Usually, the DC shunt motor is preferred as a main motor. However, an AC commutator motor may also be used. For a DC motor the speed control is done effectively by a thyristor control unit, alternatively by a Ward Leonard arrangement.

The paper is not yet suitable for marketing. The paper obtained from the paper machine has normal width. Besides, it may contain breaks or slaps and does not have the necessary format. It may sometimes be rerolled to remove any fault and tears and to provide smoother operation in the next stage, which is the slitter. In the slitter machine, the incoming side is provided with a number of knife cutters depending on the paper width desired. The webs thus formed are simultaneously wound in different rolls. Alternatively, this may be passed directly on to the cross cutter which cuts the paper according to the size. The speed of the cross cutter is changed by TIV gears. The cross cutter cuts the paper by shear action. For this purpose, the main drive motor may be a DC shunt wound motor controlled by thyristor or a Ward Leonard set or may be a AC commutator motor. Initially the speed must be very low and has to be increased gradually to avoid breakage. It has been found that the DC motor with thyristor control offers the most satisfactory solution to the requirement.

For the purpose of designing the electrical distribution system, it is desirable to adopt a duplicate busbar system in the incoming side for achieving the maximum flexibility and liability. The major portion of power is usually taken from the grid while a part of the power is generated in the mills' own power house. Since steam is required in the process, it is economical to generate steam at a slightly higher pressure to pass it through a back pressure turbo-alternator, having the facility of controlled extraction at a pressure on temperature, as required in the process. Before selecting the transformer rating, the demand factor of different sections should be ascertained. Some of the typical

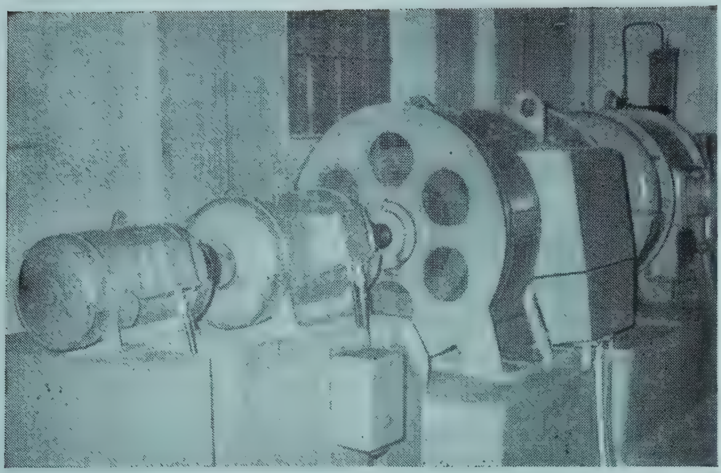


Fig. 4 M.G. Machine with Ward-Leonard set

values of demand factors for the different sections of the mill are — water supply 80%, pulp mill 80%, stock preparation 50%, vacuum pumps 70%, auxiliary machine 50%, main drive 80%. The diversity factor is of the order of 1.15. However, these values are not binding and may vary with the capacity and design.

For a fairly large mill, the power is usually available from the grid at 33 kV. Transformers need to be installed to step down this voltage to 11 kV or 6.6 kV or 3.3 kV before feeding it to the main HT distribution board. The voltage ratio of the main transformer will depend upon the voltage of the turbo-alternator, since the main HT distribution board should, preferably, have a common voltage.

It is desirable to provide duplicate busbars in the main HT DB in order to achieve maximum flexibility and reliability. For the control and protection of the HT system, duplex type panels are ideal. These panels have a walk-way at the centre with lockable doors at both ends. Usually all protective relays are mounted on one side of the panels and the meters, lamps etc. on the other. Maintenance is done from the corridor or walk-way at the centre. For the protective relays and alarm system, a suitable battery bank with charger must be foreseen. The panel can be provided with strip mimic with semaphore type indicators to give a visual indication of circuit breaker/isolator positions. In addition, annunciation windows and alarm may be incorporated to identify fault for quick rectification. The HT power from the main HT DB should be distributed to the different load centres or 'unit stations' by cable. Each such load centre or unit station will consist of one HT load break switch or ACB, one stepdown transformer and LT MCC. It is preferable to have a bus-duct between stepdown transformer and LT MCC. The LT MCC should be provided with ACB in the incoming circuit and may have inter-tripping arrangement with the HT side. From the LT MCC, the loads in that region may be fed directly by cable. Usually, in a paper mill, control is exercised near the equipment and as such push button stations near the equipment are necessary. The MCC should have provision for remote as well as local controls. The LT MCC should be sheet steel clad free standing type. Semi drawout/drawout type MCCs which have the advantage of reduced maintenance time, are becoming popular. In the event of space shortage, it is possible to utilise double front type, back to back design MCCs. Sufficient spare feeders should be foreseen, while designing the MCCs, to cater for additional load which may come at a later date as also for replacement of faulty drawout feeders during maintenance. The power and control cables should be laid underground in formed concrete trenches inside the plant. The trenches should have removable covers for maintenance and be adequately dimensioned to avoid congestion.

For obtaining proper co-ordination in all departments in order to achieve smooth production, the communication between departments/sections is most essential. This can be done by providing automatic telephones at all vital points.

Electrical technology has now developed to such an extent that it is possible to run a complete plant automatically. But in our country, such plants are not desirable considering the high capital expenditure etc. and the employment potential of a large paper mill.

COKE OVEN BATTERY AND ITS ELECTRICALS

—S. GANGULY

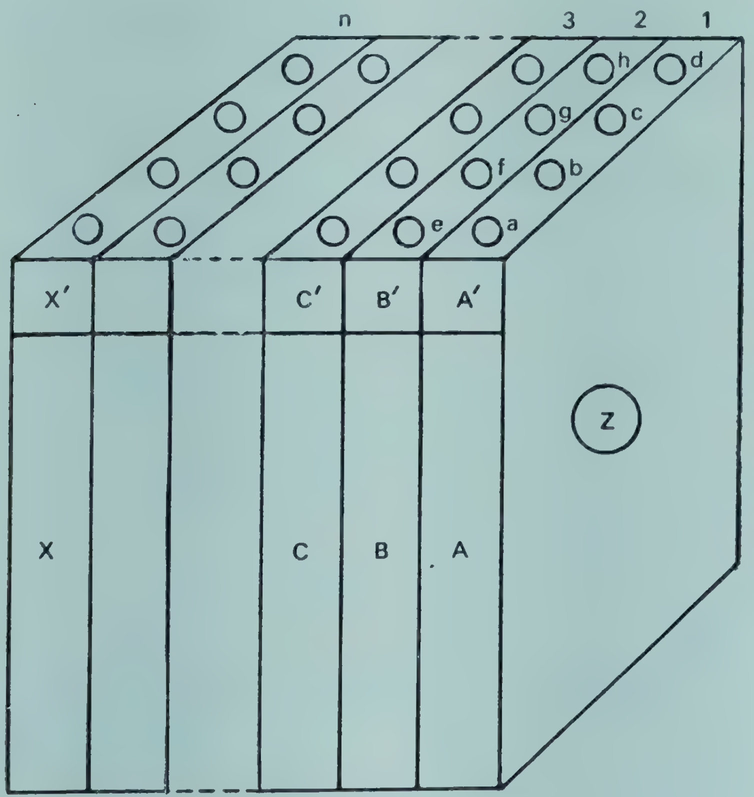
The Coke Oven Battery plays a pivotal role in the working of a steel plant. The coke produced at the coke oven is used as a fuel and reducing agent in the blast furnaces for the manufacture of pig iron. Moreover, sulphuric acid, coal tar, ammonium sulphate, benzol toluene, solvent naptha, crude napthalene and various other chemicals used in fertilisers, pharmaceutical and chemical plants are bye-products from the coke ovens.

One coke oven battery consisting of 30-50 ovens placed side by side, is equipped with the following equipment.

(i) Charging Car—for charging coal into the oven

(ii) Ram Car—for pushing the coke out of the oven

(iii) Coke Guide Car—for guiding the coke properly for putting it into the coke car locomotive, which after quenching the coke, in turn discharges it on the wharf.



a, b,...h etc. Coal charging holes at oven top
1, 2,...n etc. Individual oven forming battery
A,B,...X etc. Oven doors at ram side
A′, B′ ...X′ etc. Small doors for levelling purpose

Fig. 1 Coke Oven Battery

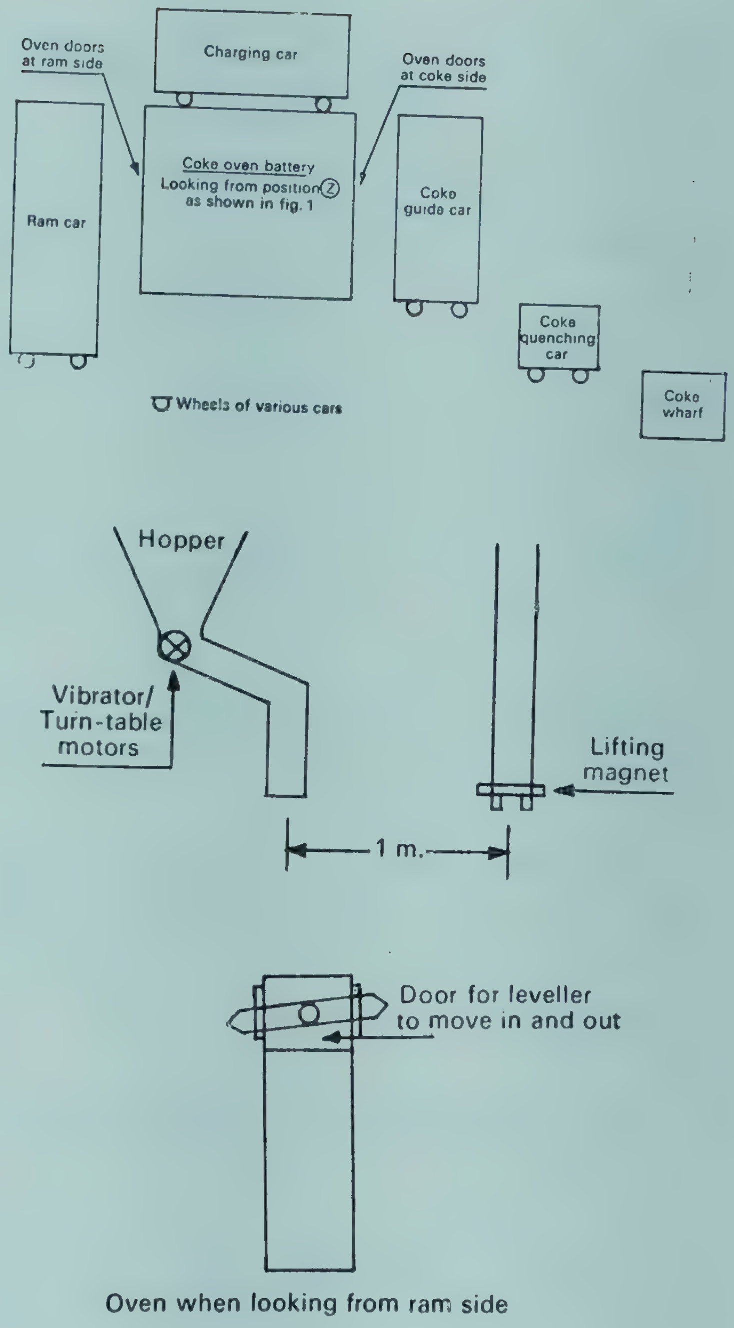


Fig. 2 Coke Oven Auxiliaries

All these cars move on rails, with power supplied to them through sliding collectors from transmission rails.

Figures 1 and 2 show the general view of a coke oven battery and its respective machines.

From the Table that follows the names of the main drives and the functions of different coke oven machines can be observed.

	Drive	Approx. Rating in HP	Functions
Charging Car	Long Travel	20 to 30	For aligning hoppers with coal bunker, lifting magnets and hoppers with the coal entry holes at the oven top, and for pipe cleaning device with ascension pipes.
	Hydraulic Pump	3 to 5	For driving electro-magnets to lift the lid of the coal entry holes at oven top.
	Vibrator or Hum Table	3 to 5	For easy/quick entry of coal from hopper to the oven.
	Pipe Cleaning	2 to 3	For cleaning ascension pipes to avoid choking by condensation of coal tar etc. and to ensure easy flow of coke gas.
Ram Car	Long Travel	35 to 50	To align the ovens with the drives mentioned below.
	Leveller	20 to 30	To fill the oven uniformly with coal poured from oven top with the help of charging car.
	Pusher	75 to 100	To push coke out of the oven with the quenching car through trough of coke guide car.
	Door Lifting	5 to 10	To lift the doors before extraction of same.
	Door Extractor	5 to 10	To extract the door aside for making way for pusher to operate.

	Drive	Approx. Rating in HP	Functions
	Spillage Conveyor	3 to 5	To throw coal, spilled from the traveller top into an empty oven from time to time.
	Door and Frame Cleaning	3 to 5	To clean the doors and the frames to avoid jamming due to leakage of coke gas containing tar etc. and its condensation outside.
Coke Guide Car	Long Travel	20 to 30	To align the ovens with the drives mentioned below.
	Door Lifting	5 to 10	To lift the doors before extraction of same.
	Door Extraction	5 to 10	To extract the doors backward before slewing.
	Door Slewing	2 to 4	For slewing the door aside for making way for 'trough' to be forwarded and for guiding coke pushed out of the oven to quenching car.
	Trough	5 to 10	To guide coke from oven to the quenching car.
	Door and Frame Cleaning		Same as those in ram car.
Coke Quenching Car	Long Travel	75 to 100	To align its wagon with the 'trough' of coke guide car, quenching house and coke wharf.
	Compressor	20 to 30	To open and close the discharge doors in the wagon, for pouring coke into the coke wharf after quenching.

Table A

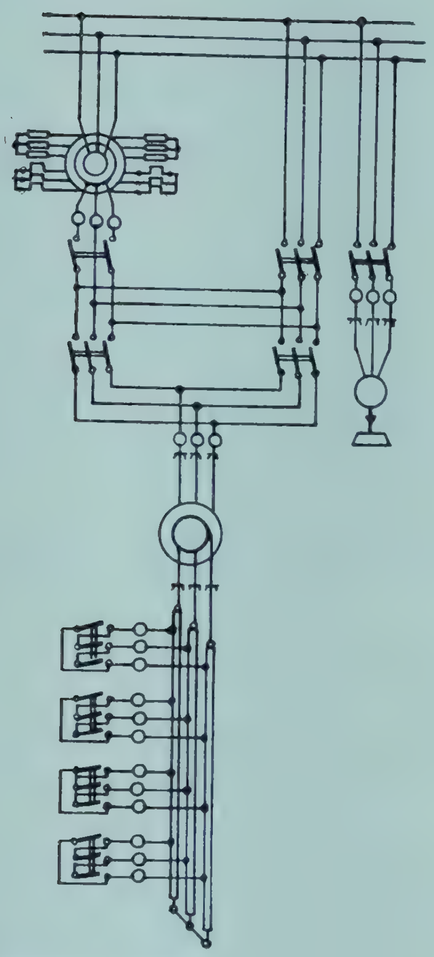


Fig. 3 Frequency Changer

Besides the drives mentioned in Table 'A', there is also some electrical equipment, viz. lubricating pumps, ventilating fans, brakes for motors, light fittings, limit switches etc. which are essential electrical components for the coke oven machine. Generally the electric supply to the coke oven plant is 230 V. or 400 V. or 440 V., 3 phase A.C.

In some coke oven plants, door cleaning and frame cleaning devices mentioned in Table 'A' are not an integral part of the 'ram car' and the 'coke guide car'. Instead there are 'daub cars' at both sides of the oven. These cars are provided with two motors for travelling along with the battery and moving a deck up or down a particular oven and the doors are cleaned manually with the help of two drives mentioned above.

For smooth operation of the various coke oven drives, various interlocking circuits are to be made and these interlockings must be fool proof. The most crucial process in a coke oven, is, that of pushing the coke out of the oven and the guiding of this coke to the coke quenching car, through the 'trough' of the coke guide car. This process needs most careful attention in the interlocking system for safety.

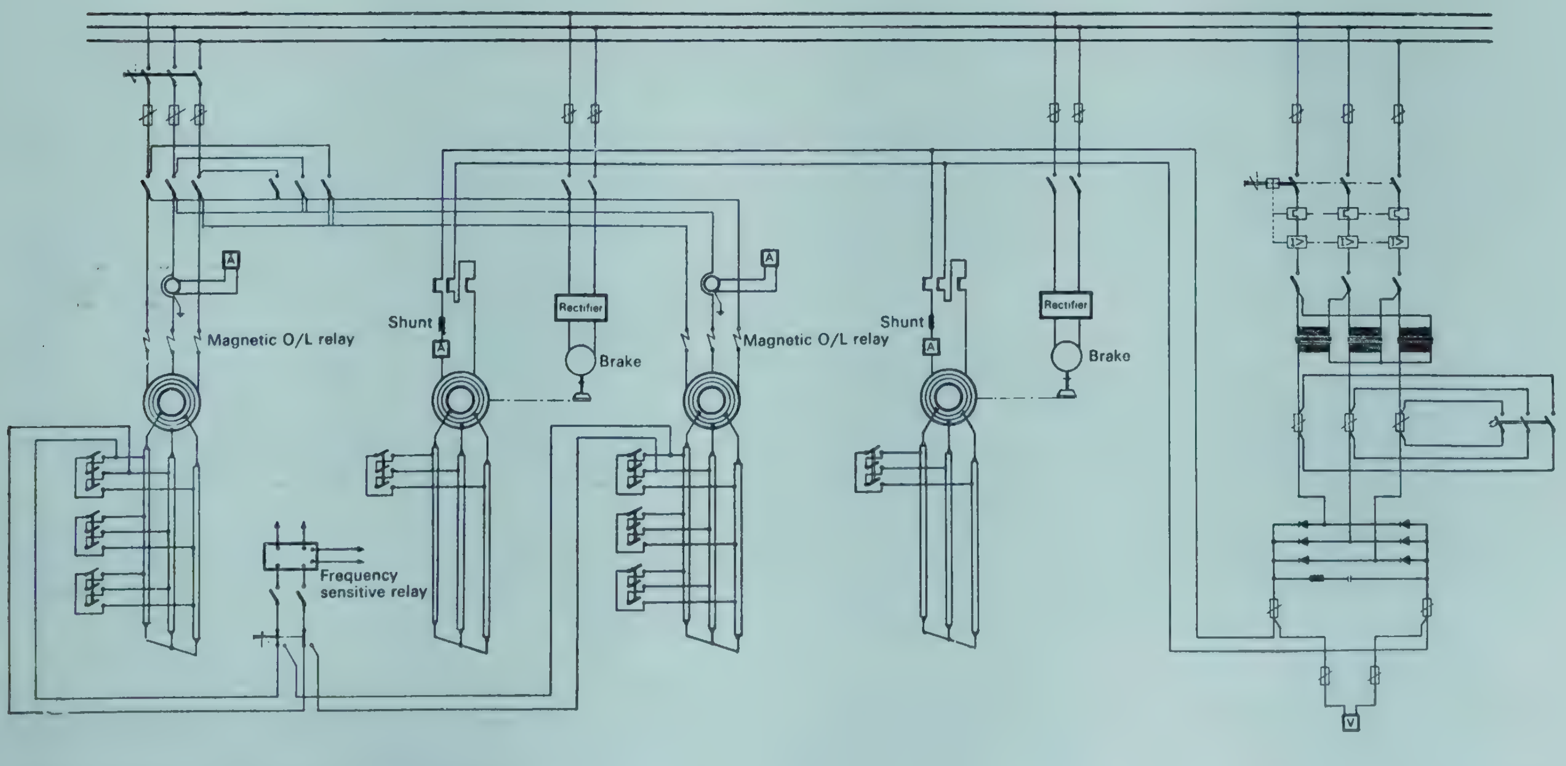


Fig. 4 Speed Control with D.C. Injection

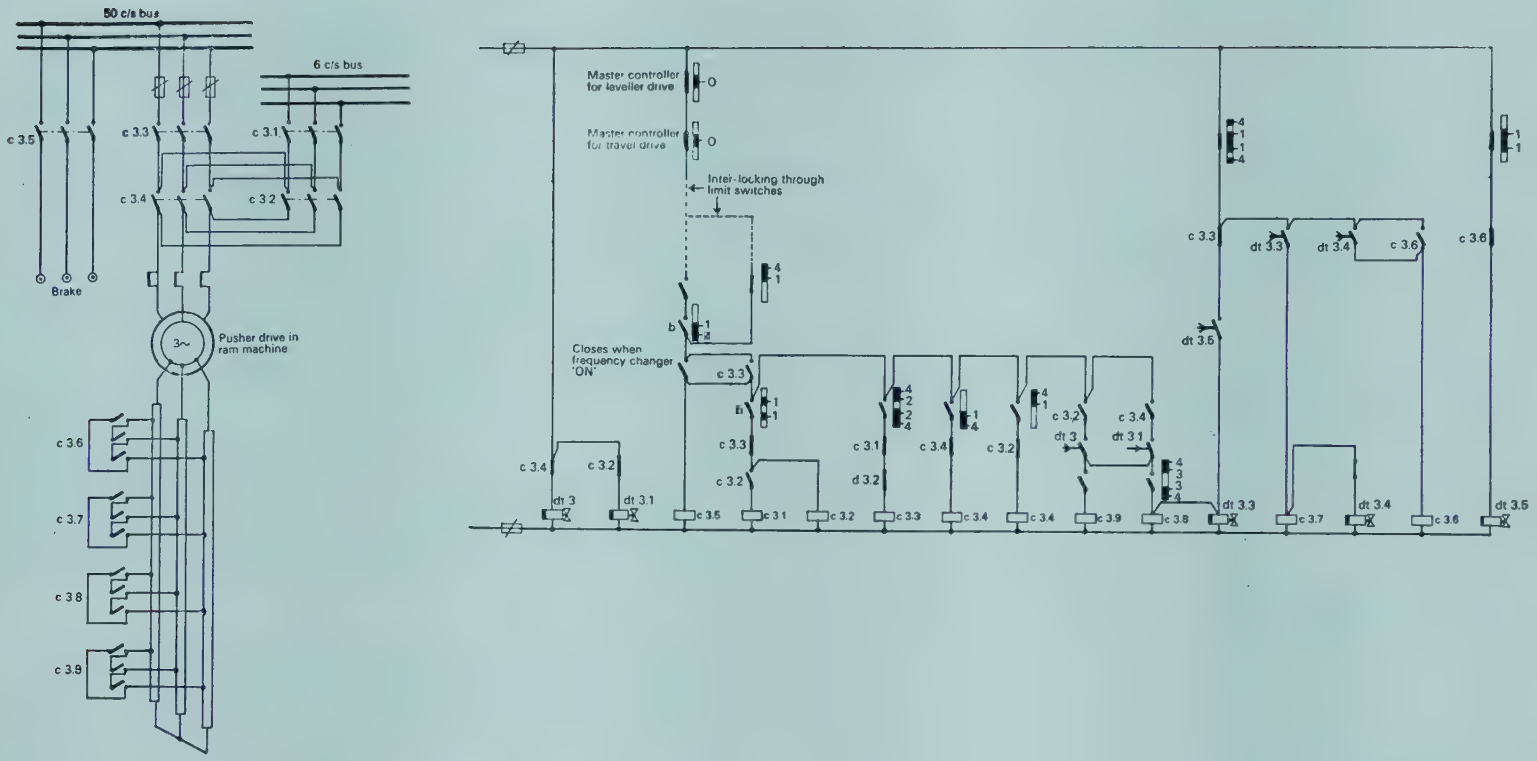


Fig. 5 Control with Frequency Changer

The safety interlocking prevents the moving of the pusher bar of the ram machine, if the coke guide car on the opposite side of the battery is not in proper position before the same oven chamber, and the quenching car is not in the proper position before the coke guide car. This system must be fool proof and suitable for the dusty coke oven plant operation. There are various methods of interlocking system, viz. "Induction Coil System" and "Isotope Ray System" etc. for the above mentioned process. The following additional interlockings are also to be incorporated for the smooth and safe control of various oven drives :

Charging Car

(a) When telescopic spouts are in 'down' position, i.e. shoved into the coal entry holes at the oven-top, the travel drive should not be operative and vice-versa.

(b) When the pipe cleaning device is in 'cleaning' position, the travel drive should not be operative and vice-versa.

(c) When the telescopic spouts are in 'UP' position, the vibrator or turn-table motors should not be operative. But when the vibrator motor or turn-table motor is running and discharging coal, the telescopic spouts should not be brought back from 'DOWN' position to the 'UP' position.

Ram Car

(a) When the travel motor is in operation, all other drives should be in the 'rest' position, i.e. leveller and ram should be in 'backward' position; door extraction should be at the side, i.e. 'backward' position, and door and frame cleaning motors should not operate—and vice-versa.

(b) When leveller is in operation ram should be in 'backward' position and vice-versa.

(c) When door extraction and lifting is in progress ram and leveller should be in 'backward' position.

(d) When ram or leveller is in progress, door extraction and door lifting drives should be in the 'rest' position.

Coke Guide Car

(a) When the travel motor is in operation, all other drives should be in the 'rest' position, i.e. door extraction, door lifting and trough drive should be in the 'backward' position and vice-versa.

(b) When trough is in the 'forward' position, door extraction and door lifting should be in the 'rest' position.

(c) When door extraction and door lifting motors are in progress—'trough' should be in the 'backward' position.

Approximate speeds of various drives are given below:

(a)	Travelling of Charging Car	: 70m to 80m per min.
(b)	Travelling of Ram Car	: 65-75m per min.
(c)	Coke Pushing by Ram Drive	: 20-30 m/min.
(d)	Levelling by Leveller Drive	: 35-45 m/min.
(e)	Travelling of Coke Guide Car	: 75-85 m/min.
(f)	Extraction of Door	: 3-5 m/min.
(g)	Moving of Trough in Coke Guide Car	: 3-5 m/min.

For various drives in coke oven machines, smooth control of speeds are very essential, especially for the motors for long travel, leveller and pusher. These motors are, therefore, of the slipring type, though other motors may be squirrel cage. The smooth control of speeds for the slipring motors can be achieved, through, either frequency changer, or DC injection to a brake motor.

In Figure 3, the basic circuit diagram for frequency changer with motor has been shown. In Figures 4 & 5, a typical circuit diagram for speed control with frequency changer and DC injection respectively have been shown.

The two different controls are discussed here:

Frequency Changer

By feeding an induction motor at a low frequency, creep-speed can be achieved almost without losses. Siemens make frequency changers type RUF 166 and RUF 186; for this type of service they are designed to give an output of six cycles, thus making possible a speed ratio of about 1:10 between the creep-speed and the rated speed.

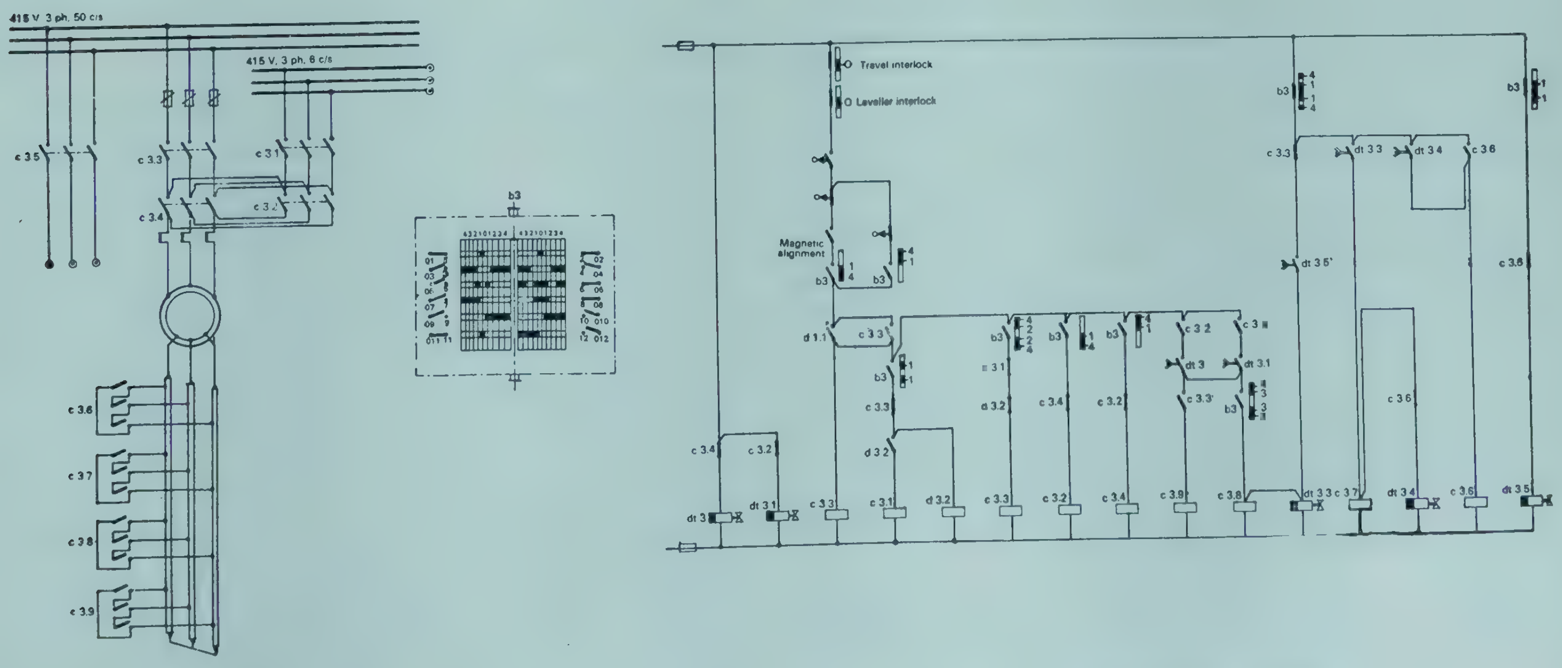


Fig. 6 Circuit Diagram for Pusher Drive in Ram Machine (Speed Control through Frequency Changer)

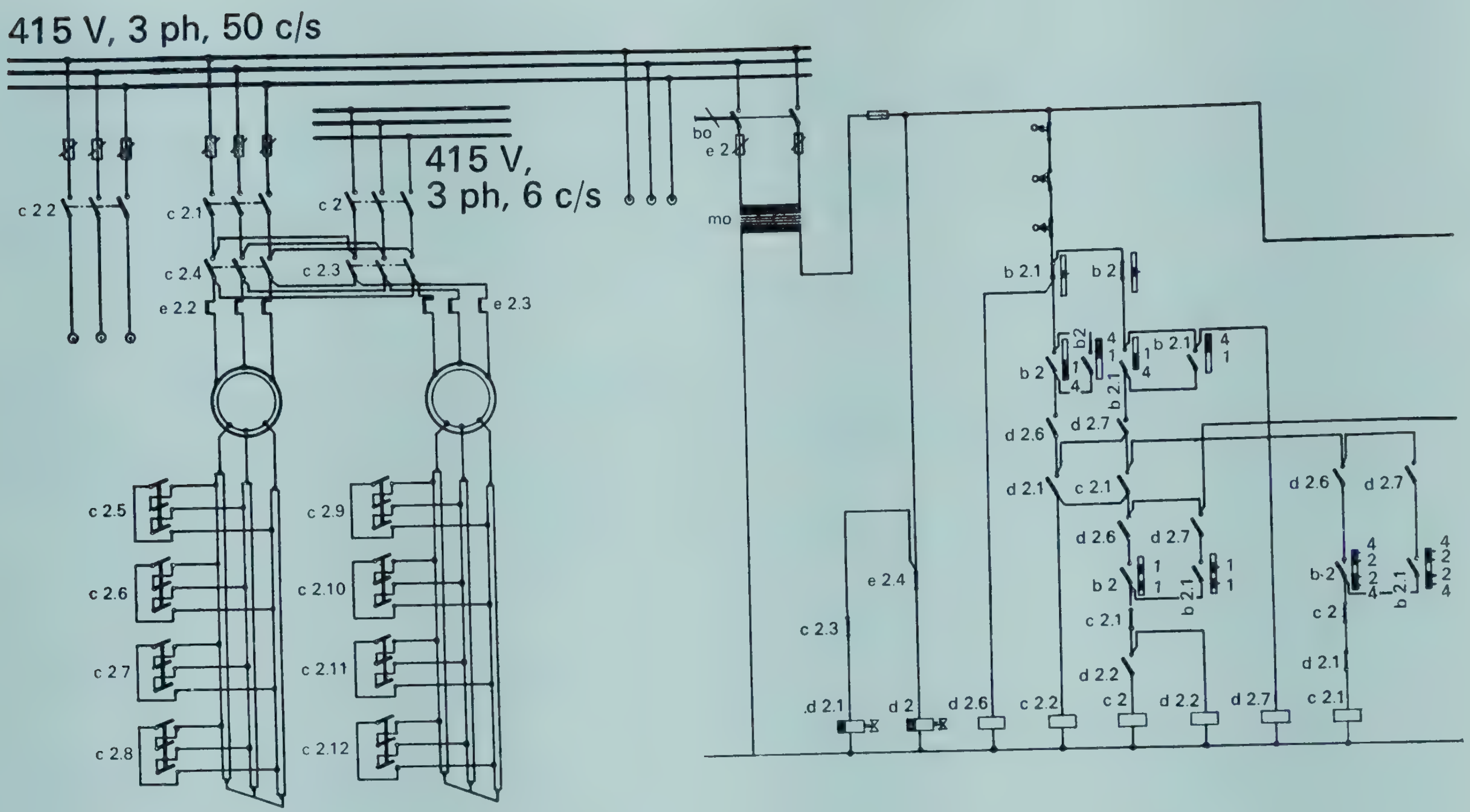


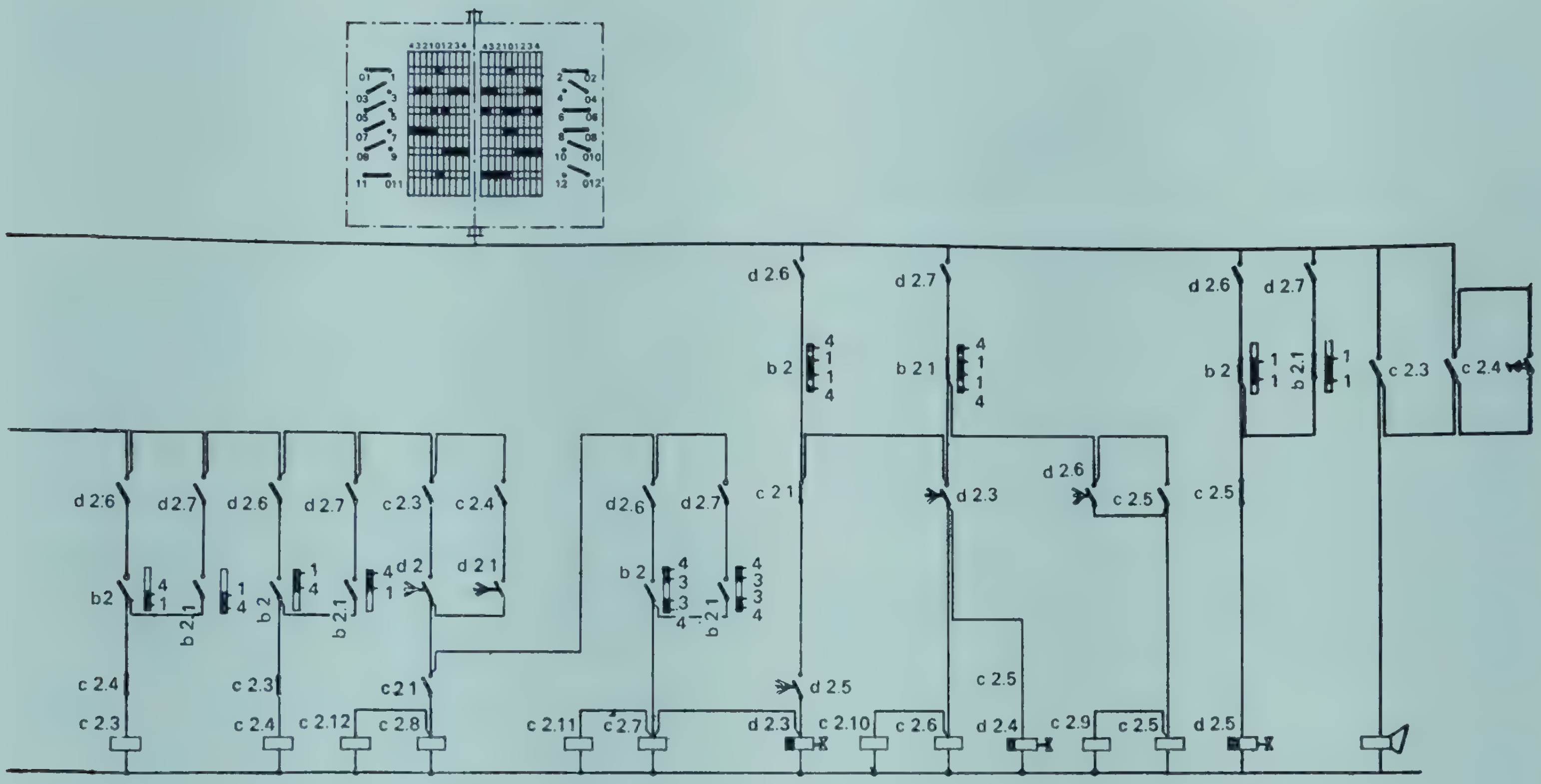
Fig. 7 Circuit Diagram for Charging Car Travel Drive

With these machines the rotor winding connected to the sliprings is fed from the mains, whereas the commutator is connected to a second special winding on the rotor. Connected in series with the stator winding, which is coupled inductively, is a resistor which reduces the speed of the rotor from synchronous speed, in the same manner as with a slipring rotor. The frequency of the three phase AC, collected from the commutator, is proportional to the rotor slip and can be varied within narrow limits by altering the stator circuit resistance. Since the voltage across the commutator is likewise reduced in proportion to the frequency, the rating of the frequency changer as compared with that of the drive motor can be reduced in approximately the same ratio.

Thus, for example, a 20 kW hoist motor requires a 4 kVA frequency changer and for a 40 kW motor a 8 kVA frequency changer is adequate, whereas, for a 100 kW motor a frequency changer with a rating of 25 kVA is necessary.

DC Load Brake Motors

In Figure 4, a typical basic circuit diagram has been shown with two each, of long travel and DC load brake motors. Here the creep-speed is achieved unlike as in the frequency changer. In this case, all four motors are identical. One each of travel and DC load brake motors are coupled together; the travel motors being fed from the usual supply, viz. 50 c/s. system and the DC load brake motors, being fed from outgoing terminals, of a bridge rectifier, of a selected DC voltage/current, as shown. By inserting suitable resistances in the rotor circuits, the desired braking torque is applied and consequently creep-speed is achieved. A DC injection is made to the stator winding, connected in star or delta. However, a delta



connected stator winding is more suitable since this helps the distribution of DC excitation current more uniformly and also, obviously, a maximum DC excitation current can be passed through the stator winding.

Sample Calculation for Braking Through DC Injection

Let type of slipring motor used be 1LT2 176-8, which has resistance/phase (stator) as 0.130 (at 27° C), rated current as 80A.

Stator Circuit: Equivalent Stator Circuit:

R_{eq} at 100° C. $=$ 0.111

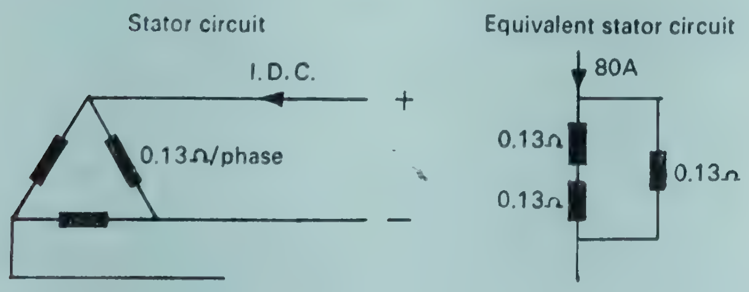


Fig. 8

Max. allowable DC Braking current I_{DC}

$$= 2.2 \times \frac{\text{Stator Current}}{}$$

$$= 2.2 \times \frac{80}{3}$$

$$= 102\text{A}$$

DC Injection Voltage

$$V_{DC} = 0.111 \times 102 = 11.3\text{V}.$$

Taps provided in Rectifier Trafo. $=$ 6V, 12V, 15V&18V.

I_{DC} corresponding to V_{DC} (18V) $=$ 162A.

$\therefore$ kVA rating of Rectifier Trafo. $= 1.05 \times 18 \times 162 = 3.1$ kVA

Figures 5, 6 and 7 show typical circuit diagrams of a generator motor, pusher drive motor and charging car travel-drive motors, controlled through the frequency changer.

ELECTRIFICATION OF A NYLON PLANT

—A. M. BHATJI

Before we go into the details of the electrification of a nylon plant, it is essential to understand the basic process of the manufacture of nylon yarn. One of the by-products of crude oil refineries is naptha. From naptha, caprolactum is extracted. Caprolactum is polymerized and the product is called Nylon 6. Molecules of caprolactum react with each other under specific conditions and form a big molecule which is Nylon 6. Explaining in mechanical terms polymer (nylon 6) is nothing but a chain consisting of links each of which is called a monomer (caprolactum). Further, as it is made entirely by man, it forms one of the group of fibres known as man-made fibres. The longer the chain consisting the molecule, the stronger is the yarn.

Caprolactum is melted and at a definite temperature it begins to polymerize in the presence of water and catalyst. The longer it is held in this condition, the longer is the polymerisation chain. Molten caprolactum, however, has a very high affinity to oxygen and can oxidise easily in contact with atmospheric oxygen. Hence, in the molten stage, caprolactum is handled in stainless steel vessels, and is kept in an inert atmosphere, usually nitrogen. Further, a catalyst, usually an acid is required for aiding the process of polymerisation. Besides these, there are some additives used at this stage; such as titanium dioxide for opacity (as otherwise the yarn and ultimately the cloth would be completely transparent) and other optical brighteners. In inferior quality nylon yarn where this chemical is not added, the yarn/cloth is seen to take on a yellowish hue when exposed to sunlight. The vessel in which the polymerisation takes place is known as the Polymerisation Reactor. The molten polymer is taken out in strands and the strands, after passing through pinch rollers to regulate the size, are cut into tiny pieces known as chips.

The chips are then taken to separate melting vessels again and are taken out as fine yarn of various grades and sizes. This is usually done today by extrusion process. The yarn is then rewound in the winding machines to give the finished nylon cop.

From the point of view of electrification, the salient points are :—

(a) The presence of nitrogen at nearly all stages is extremely essential. Hence, all electrical equipment handling nitrogen, and more important, the nitrogen producing plant which is usually part of the factory complex, must not fail. Depending on the storage capacity at various stages and the availability of standby equipment, all electrical equipment connected with nitrogen thus assumes great importance.

(b) The temperature at which caprolactum reacts is very critical. Even a very small variation can change the properties (particularly the viscosity) of the finished product. The temperature is attained usually through heat exchangers where the source of heat is a liquid which has a sharply defined boiling point (at a temperature which suits the process best). This liquid has to be maintained at a definite temperature within a very close range and this is done by means of electrical heating elements. The control of the temperature involves sophisticated electrical equipment such as thyristor controls.

(c) Obviously, where temperature control itself is so critical, power failure is unimaginable. A temporary power failure of a duration of a fraction of a second to about ten minutes, may involve draining away caprolactum till the correct properties are attained again. A longer power failure can result in the solidification of the polymer and caprolactum in all pipe lines and vessels. Thus, in case of a longer power failure, the polymer is usually totally drained away resulting in huge losses.

(d) The yarn produced is generally of a very fine gauge and extremely fragile. Power failure of even a fraction of a second results in a break and re-starting involves loss of large quantities of yarn during take-up.

(e) Further, nylon yarn is extremely light and whenever yarn is allowed to come downwards by purely gravitational means, a slight but definite positive difference of atmospheric pressure has to be maintained between the upper and the lower levels.

This involves very close control of the air supply and exhaust system in the two regions and the whole area has to be closed by doors with airlocks.

(f) It should also be noted that continuous friction

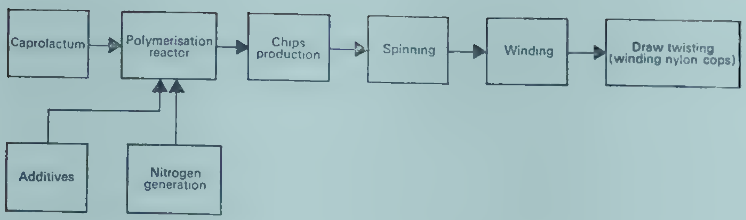


Fig. 1 Block Diagram of a Nylon Plant

of nylon yarn over insulating material results in the accumulation of static charges. Thus, particularly where several strands run in parallel, they are repelled from each other. This is eliminated by means of static eliminators.

(g) Nylon yarn at all stages of production and particularly in the finishing stage, attracts dust due to static charges. Thus, air washers, fresh air supply and air exhaust systems are of prime importance.

(h) Last but not least, it should be remembered that nylon yarn is very soft and if wound as in the case of cotton yarn, will tend to slip off. Hence, in the winding machines, the winding pattern is regularly disturbed by means of variable speed drives (usually automatically controlled PIV drives). Also, the winding speed of various gauges of yarn (known generally as the DENIER of the yarn) is different. This change in speed is usually achieved by a variation of the frequency of power supply to the winding machine drives.

Besides the points mentioned above, there are of course the auxiliary departments such as the water supply, boiler house for steam generation, laboratories, workshop etc., which require power. However, these are standard auxiliaries found in most factories and power supply to them does not pose any problems.

On the basis of this discussion it is seen that the power supply to a nylon factory must be divided under the following heads :

(a) Critical: under this head, all loads which cannot tolerate a break in power supply of even a fraction of a second, are covered.

(b) Essential: under this head all loads which can tolerate a break in power supply of upto 10 minutes are covered.

(c) Normal: These loads generally do not affect the production of the factory even on prolonged shutdown.

The ideal conditions required from the electrical point of view in a nylon plant are :

Frequency variation between 49.1 and 50.1 cycles per second.

Voltage variation :±2%.

Unfortunately, the above conditions are very difficult to meet in most places in India and hence the quality of the nylon suffers.

Distribution of Power: ALT-1

A general block diagram is shown in Figure 1, of the manufacture of nylon. Figure 2 shows a suggestion for power distribution to a typical nylon plant of 2.5 tonnes per day capacity. In the power supply single line diagram shown in Figure 2, the supply voltage is assumed as 22 kV, which is frequently the case. The main features of this scheme are given below :

The power supply required for the nylon plant has to be very steady i.e., a supply failure, or even a variation of the voltage and frequency beyond the specified limits mentioned above, would be detrimental to the production of the nylon yarn. Hence, two separate lines are absolutely essential for feeding power. These lines also should come directly from the generating station/substation of the supply company without being tapped off for any other consumer. This will ensure that a fault on any other consumers' line does not affect the power supply to this plant. Further, each of these two lines should be sufficient to cater to the full load requirements of the entire plant. The 22 kV switchboard will, therefore, have two incomer breakers and one bus coupler, to ensure automatic switchover from one line to another, in case of failure of any one of the two supply lines. As 22 kV breakers are very costly, it might be sufficient to use load break isolators for the outgoing feeders to the four transformers, though, in the single line diagram they have been shown as motor operated circuit breakers.

For critical loads, the power supply is through one of these transformers with alternative supply from a diesel generator. The circuit breakers from the transformer, diesel generator and the bus coupler have also to be so linked up, that, in case of failure the power supply is automatically transferred to

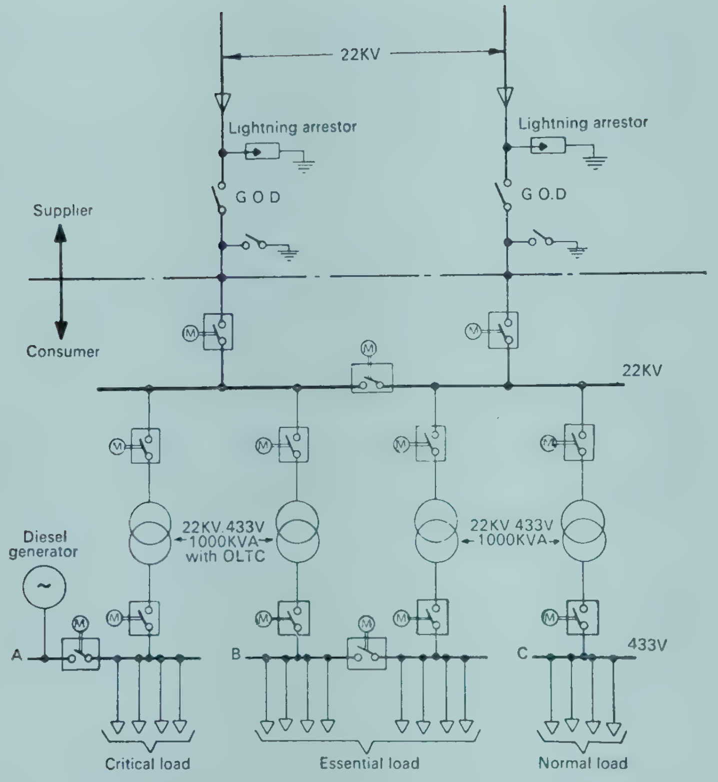


Fig. 2 Basic Single Line Diagram for Power Supply to a Nylon Plant ALT-1

the diesel generator. However, as already explained above, the critical loads cannot tolerate a power failure of even the smallest time period. Hence it is essential that the switchover from the transformer to the diesel generator should not affect the continuity of power supply. As, in India, we have diesel generators only, capable of automatic starting, these are preferred for the emergency supply to the critical loads. The ideal set, of course, is the no break diesel generator set, in which the fly-wheel effect ensures continuity of power supply during transfer from the normal to the emergency supply. However, these no break sets have to be imported at present. Alternatively, control voltage to the critical drives is through a small no break set which can be imported. However, in this case continuity of power supply cannot be ensured. Due to these factors it is sometimes found advisable to supply the critical loads continuously by the diesel generator.

In the case of essential loads a short duration power supply failure can be tolerated. Hence the ideal supply to these loads will be through two transformers. The main LT distribution board shown as 'B' in the single line diagram is supplied power from two transformers with the bus coupler in the middle so as to ensure automatic changeover of load from one transformer to another in case of an emergency. It may not always be possible to have one main distribution board as shown here. The Board 'B' can in that case be split up into two boards, linked up by means of cables, with tie feeders in place of bus couplers.

In the case of normal loads, no special precautions are necessary for power supply and the standard distribution system as shown in the single line diagram is quite sufficient.

Distribution of Power: ALT-2

From the point of view of economy, however, it is advisable to change the power supply system as shown in Figure 2. In this second alternative the incoming voltage of 22 kV is first stepped down to 6.6 kV through a transformer of 4 or 5 MVA capacity.

If it is feasible from the point of view of economy it may be better to use two transformers instead of one so as to ensure uninterrupted power to the plant in any emergency. Morever, these transformers should have complete protection so as to ensure trouble-free operation. It is therefore recommended that besides the normal protection such as Buchholz relay etc., winding temperature indicator and differential protection, should also be incorporated with this transformer. As steady voltage to the plant is very essential, it goes without saying that the OLTC (On Load Tap Changer) should be completely automatic and should be controlled by means of high precision voltage sensing relays. Any expense incurred for the protection of these transformers will repay itself within a short period and hence it is not advisable to economise on this protection.

The salient features in this case are :

Minimum number of switchgear on the 22 kV side will be required. As 22 kV switchgear is more costly than 6.6 kV switchgear, this system is more economical. Further, each of the individual transformers can be located at the load centres and 6.6 kV cables can be run from the HT Board in the outdoor substation to the various transformers as shown in Figure 3. As for the transmission of the same amount of power, LT cables are more costly than HT cables of 6.6 kV grade; this further ensures economy

in distribution. Further, as the cost of the OLTC is very high compared to the cost of a 1000 kVA transformer, it is more economical to use it with a 4 MVA transformer.

Distribution Boards

In either of the two schemes mentioned above the power supply on the LT side is taken through power control centres/circuit breaker panels from the transformers directly. From these power control centres, cables are run to the various distribution boards located in the plant through switch fuse units. Certain machinery which have their own control panels will also receive power directly from these power control centres.

The distribution boards located throughout the plant can be essentially of three different types. These are further described below :

Distribution Boards housing the various switchgear such as switches, fuses, contactors etc., in cast iron housings can be used. These robust distribution boards and are completely dust-proof. This system offers a compact modular cast iron clad design for low tension distribution boards. It is built up with the help of standard cast iron housings of matching dimensions and various standard accessories. A number of such housings are joined together to form the busbar chambers and the various incoming and outgoing feeders. The feeders can be distributed above as well as below these busbar chambers as per requirements. As this distribution board is built up of individual modules, it is extremely easy to extend/modify it whenever required.

A second type of distribution board which can be used consists of various switchgear items mounted in sheet steel housings. This distribution board is also built up with the help of standard prefabricated housings of matching dimensions and various standard accessories. A number of feeders can be accommodated in each of the housings and the distribution board itself can be easily modified or extended.

However, in view of the fact that power supply for the nylon plant is so critical, it is advisable to use yet a third type of distribution board which is described here. In the second type suggested above as several feeders are mounted in each of the housings, it might be necessary on some occasions to switch off the entire panel for maintenance purposes. Whereas, in this third type of distribution board known as the compartmentalised Motor Control Centres, it is easy to carry out maintenance on any feeder without disturbing the other feeders. These MCCs are sheet steel clad, floor mounting type in fully compartmentalised design. Basic design is offered in a semi-drawout type; however, it can be easily converted to fully drawout type, by additionally mounting the plug-in contacts on the cable side. The control and auxiliary connections can also be of the plug-in type as per requirement. This system of distribution boards has a busbar chamber at the top and feeder compartments of modular dimensions situated below. If

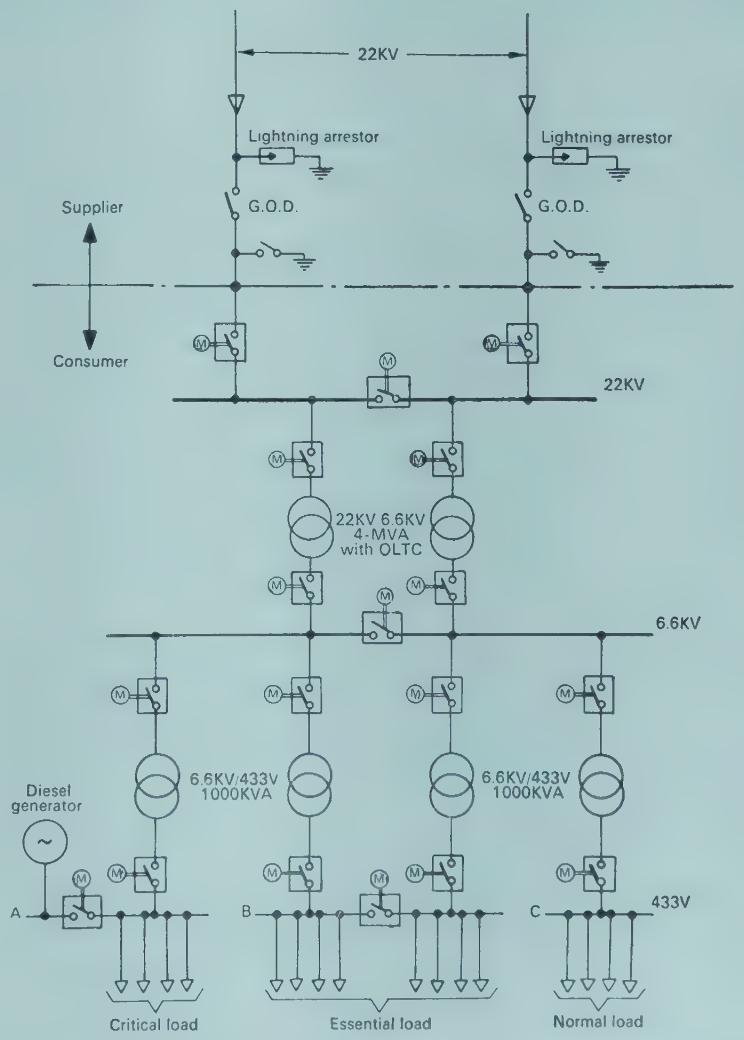


Fig. 3 Basic Single Line Diagram for Power Supply to a Nylon Plant ALT-2

necessary the busbars can also be located at the bottom and the feeders located above the busbar chamber. On the right hand side of each panel there is a vertical cable alley which permits independent cable entries to each of the compartments. The standard compartments are of adjustable type and can be converted from one size to another, depending on the requirement of space in the feeder trolleys. This distribution board can also be offered in either single front or double front execution.

Cables

For the distribution of power, Tropodur cables are recommended. These cables can be run along any structure or also on false ceilings. No special protection or laying procedures are required for these cables. They are also completely immune to any aggressive surroundings such as dust, fumes and vapours present in the atmosphere. These Tropodur cables are also available upto 11 kV grade and hence can be used throughout the plant. Tropodur cables are thermoplastic insulated cables i.e., with PVC insulation and sheath. Since there is no impregnating compound in these cables, they can be laid vertically and on steep slopes. Further, there is no danger of bleeding at lower level sealing ends. Due to their light weight, Tropodur cables are easy to install and handle. Further, the bending radii being small, they permit the termination of these cables in limited space. Further, advanced techniques, such as Tropolin jointing, are also available today to ensure fool-proof jointing of these cables. The cold setting nature of the casting resin ensures that there is no risk of damage to thermo-plastic PVC insulation. Tropolin consists of a modified semi-liquid opaque casting resin and appropriate hardener. The curing takes place within 5-7 hours only, depending on the ambient temperature and size of the mould.

Instrumentation

It can be seen from the details of the production given above that the temperature of melting of the caprolactum, the difference in atmospheric pressure between the winding and spinning departments etc., are very crucial. The temperature of melting of caprolactum in the polymerisation reactor as well as the temperature of melting of the chips in the spinning department are monitored continuously by means of recorders-cum-controllers. The set point temperature is compared with the actual temperature sensed by the recorder and the error signal is amplified for operation of the thyristor drive unit which will increase or decrease the voltage to the heating elements, as required, until the error is brought down to zero. Suitable precautions should, however, be taken to see that the operation of the recorder/controller is dampened to allow time for the sensing of the temperature from the sensing elements. Otherwise, if the operation of the controller is too fast, the temperature will start hunting and will take a long time to reach the set point.

The atmospheric pressure difference, between the winding and spinning halls, is ensured by means of blowers, exhaust fans and damper drives for controlling the dampers installed on the exhaust fans. The atmospheric pressures in the two halls are sensed and compared in a controller. The difference in pressure required is pre-set in the controller and is constantly maintained by means of regulation of the damper opening.

The sensing, recording and controlling of the temperature of melting of caprolactum in the polymerisation reactor is also achieved by means of controllers/recorders as already described above.

Due to the fact that dust particles have a tendency to stick to the nylon yarn, it is essential to make the winding department and the draw-twisting department entirely dust-proof. This is done by means of air washers installed in these halls where the inlet air is sent through a water-spray for removing all dust particles. Further, it is also recommended that a two door air lock system is installed, particularly in the winding and spinning departments, to ensure the exact difference in atmospheric pressure and also a dust proof atmosphere.

Conclusion

On the basis of the above, it can be seen, that, electrification of a nylon plant is of a specialised nature, where the most important feature is stability of power supply to the various loads. Due to the inherent nature of the factory being necessarily very clean and devoid of all dust particles, the aesthetic nature of the electrification also assumes great importance.

New Siemens MOS Centre

Siemens MOS Centre, Munich

At a cost of DM 20 million Siemens has set up a plant for the production of MOS components in Munich. To start off with, an annual turnover of DM 100 million is planned. Thus, the company can rightly claim to be the leading MOS manufacturer in Europe. The new facilities essentially comprise six diffusion ovens for doping the semi-conductor crystals with impurities and three ion implantation systems for ICs with particularly low operating voltages. Siemens is justified in making such a large investment, as MOS technology—which has already reached a stage where 15,000 transistors can be integrated on a few square millimeters—is the technology for future large-scale integration.

Integrated metal oxide semiconductor (MOS) circuits require fewer fabrication steps than bipolar circuits, have smaller structures and consume less power. It is therefore possible to accommodate a particularly large number of transistors on a limited area. Engineers were discussing possible methods of manufacturing such circuits as early as 1961, five years later the first samples were on the market. In 1974 the world-wide MOS market exceeded DM 2,000 million, accounting for about one-third of the overall integrated circuit market. Over the next few years MOS sales are expected to increase at a rate of 30%, a figure well above the average for the components sector. Siemens has so far developed approximately 200 MOS circuits for a wide variety of applications. Siemens has now opened a completely new MOS centre, in which MOS circuits worth about DM 100 million can be produced annually. This centre takes the place of a number of decentralized, widely scattered production locations. Its overall isolation from the environment allows a previously unattainable but now obligatory freedom from dust during the production processes.

Siemens chiefly employs p-channel metal-gate technology for the production of MOS circuits. Ion implantation is used to reduce the operating voltages. ' Depletion load ' technology (gate with variable load resistance) is used for low and widely fluctuating voltages and also for reduction of the power draw. Memories are exclusively built with p-channel silicon gates. For particularly small structures an n-channel process with silicon gate is being introduced. These components permit progress toward a lower supply voltage and, in particular, an increase in computing speed.

MOS technology has gradually taken precedence in almost every sector of electronics. The main field of application was originally EDP systems. In the meantime, MOSFETs have become standard components in communications and measurement applications and in automotive and consumer electronics. In the entertainment field, for example, electronic organs and remote control units for TV sets are equipped with these modules. For such a wide range of applications, bipolars would be too expensive. MOS technology, in contrast, provides a cost-effective solution on account of its far higher—and steadily rising—degree of integration.

Brushes and Brushholders for Sliprings

Electrographitic or metal-graphite brushes are mainly for the sliprings. The brushholders are of the box, Figure 2, or arm, Figure 1 type.

Double Box-Type Brushholder

The holder takes two brushes mounted one behind the other, seen in the tangential direction of the slipring Figure 4. The clamping piece for securing the brushholder on the brush stud is located in the centre between the two holders.

Double Arm-Type Brushholder

This type of brushholder Figure 3 is used in special cases with slipring motors and brush-lifting gear. This type of holder has either one or both arms movably connected to the clamping piece. The brushes are normally screwed to the arm—in special cases clamped—by which they are guided and pressed down. The brushes can move in the holder to compensate for wear.

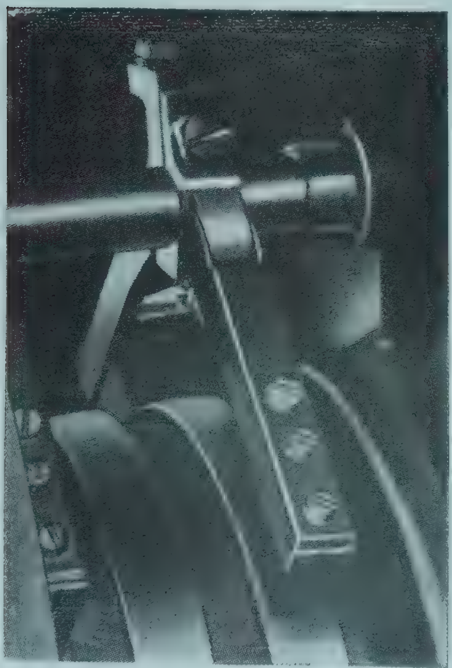


Fig. 1 Double Arm Type Brushholder

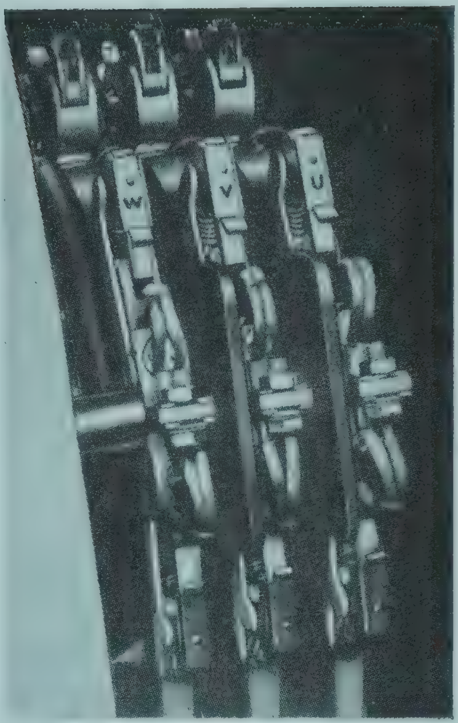


Fig. 2 Double Box Type Brushholder

Checking at Regular Intervals

Under normal operating conditions, only the following parts of machines with sliprings have to be checked : Sliprings, brushes and brushholders, since current collection—and thus the wear on the brushes and sliprings—is primarily dependent on the condition of these three parts.

The following measures are recommended for maintenance of these parts :

Sliprings

The rings must always have a smooth surface and run true. The following should thus be noted carefully :

Check the sliprings for tight fit by lightly tapping the slipring assembly with a hammer of synthetic resin; also check the winding connections on the sliprings for firm contact and tighten them up, if necessary.

It is essential that dust—particularly dust with abrasive properties—and harmful vapours, lubricating oil and grease, etc., be kept away from the sliprings, since they would destroy the smooth surface of the rings. Wipe the sliprings regularly with a dry cloth. Proceed very carefully with grooved sliprings. Use only firmly textured, non-linting cloths. Never apply dressings to the sliprings, since these are mostly harmful.

Rough spots on the slipring surfaces can be removed by grinding with fine glass—or sandpaper (preferably with the machine running) using paper of successively finer grain.

Fig. 3 Single Arm Type Brushholder for Sliprings

Fig. 4 Double Brushholder (V-holder)

Note : Excessive grinding, particularly with unsuitable abrasives (e.g. coarse glass—or sandpaper) should be avoided, since otherwise the smooth surface would be destroyed and the sliprings become wavy. After grinding, thoroughly remove the dust.

The sliprings should be resurfaced by skimming or grinding if dust,

dirt or overload have caused the rings to run out of true or if grooves have formed. If only minor damage or eccentricity of the order of a few hundredth of a millimeter are noticed, the sliprings should be ground by running the motor with the rotor in place, whereas damage of the order of some tenth of a millimeter and more normally requires removal of the rotor and skimming of the sliprings on a lathe.

If a diamond cutter is used for skimming, run the machine at maximum rated speed. Skimming by means of a steel tool should be carried out at a low speed, beginning with a coarse and proceeding with a very fine cut depth; set the tool as short as possible to prevent vibration.

Important : Before starting skimming, thoroughly clean the tapped centering holes in the shaft ends. The rotor must run perfectly true in relation to the shaft journals.

The sliprings are now finished with fine glass—or sandpaper as described above and polished to a high gloss with a dry piece of acid-free leather. If this step is omitted, dust will be producted by abrasion and the brushes will be subjected to excessive wear. The sliprings should be re-polished with leather at regular intervals, unless they wear themselves smooth.

Brushes, Brushholders

Proper current collection, sparkless running and minimum wear on the brushes presuppose careful checking of the holders. Close attention should therefore be paid to the following points :

Note : Always use brushholders of the same type in a given machine.

Check the sliprings for sparking of the brushes when the machine runs up to speed. Check the brushholders carefully to see that all parts are making good contact (cable lugs, proper seating of the clamping pieces, etc.). The brushholder spring must not jam. Brushholders on which the stream of cooling air impinges should be examined for foreign matter and dust; to do this, remove the carbon brushes from the holders (leave the pigtail leads attached, if possible) and blow out the brush guide with dry compressed air or use a vacuum cleaner). The air pressure should not exceed 5 kgf/cm^2.

Caution : Do not damage the brushes by compressed air (e.g. do not break the edges by hitting them with the air nozzle).

If firmly adhering dirt is noticed, clean the brushholders with a non-linting rag or with a brush. Do not use oakum or metal objects. If trichlorethylene or petrol is used in special cases,

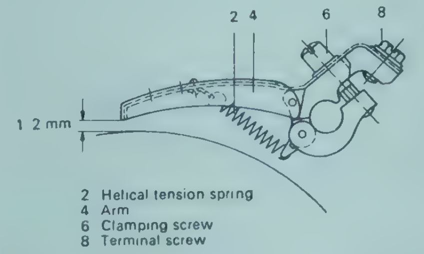


Fig. 5 Adjusting the Arm-Type Brushholder (without brush)

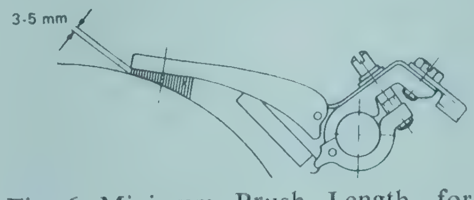


Fig. 6 Minimum Brush Length for Arm-Type Brushholders

protect the surface with a strip of presspan or similar material. During cleaning, take care to prevent a mixture of dust and trichlorethylene from forming which might be drawn into the machine later. Petrol or trichlorethylene should therefore be used sparingly. Make particularly sure that no cleaning agent remains trapped in the spring casing of the brushholder.

Fitting Arm-Type Brushholders

Remove the carbon brush from the arm of the holder and tighten up the clamping screw 6, Figure 5, when the front edge of the arm is still approx. 1-2 mm from the surface of the slipring. There is no fixed relation between the position of the arm-type brushholders and the particular direction of rotation.

Brush Length

Check the brush length. If the brushes are worn down, replace the complete set. For the minimum length permitted for the brushes, see below :

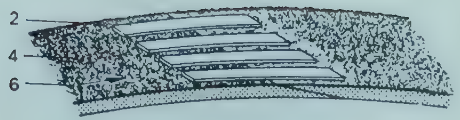
Box-Type Brushholders: The brush must not be shorter than 15 mm, otherwise the contact surfaces may be damaged by the pigtail lead.

Arm-Type Brushholders : Replace the slipring brushes as soon as the lower holder edge is at a distance of 3-5 mm from the slipring surface, Figure 6.

Precise values can be obtained from the manufacturer of the machine.

Replacing the Brushes

If all the brushes of one or several holder studs or bars are to be



2 Adhesive tape
4 Emery cloth
6 Direction of rotation

Fig. 7 Fixing the Emery Cloth on the Surface of the Slipring. (The overlapped ends of the emery cloth are flattened out).

replaced simultaneously, the brushes should be bedded. Only in the case of small slipring machines can bedding be dispensed with.

Caution: Always apply the pressure finger carefully to the brushes.

Note : In the case of new machines or those which are installed in new surroundings where other conditions prevail (different humidity, presence of chemically aggressive gases, etc.), it must be generally expected, that the brushes will have to be changed sooner during the initial operating period, since a new oxide film has first to form on the sliprings.

In the case of arm-type holders, lift off the holder (without slackening the clamping piece), firmly press the brush into the holder and tighten the fixing screw.

Re-ordering Brushes

To prevent interruptions in operation, always keep a complete set of brushes on stock. Always use brushes of the same type (do not change the type before discussing the matter with the suppliers). To permit proper identification, always quote the machine type and serial number or the type of brush and the tangential (width), axial (length) and radial (height) dimensions. The type of brush is engraved in the top part of the brush.

It is recommended that a used brush be sent to the manufacturer to enable him to evaluate the service value of the old set.

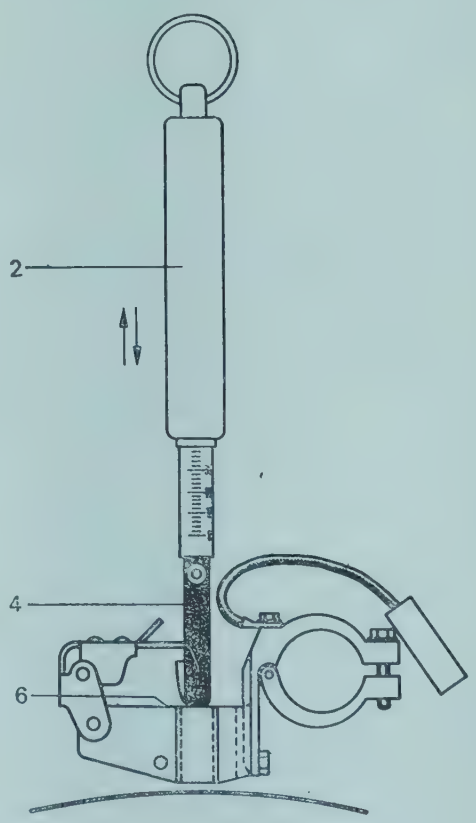
Checking after Changing the Brushes

Ensure that the brushes move easily in the brush guides. Check all the terminal screws for proper contact. Poor contact causes the pigtail leads to burn out, among other damage.

The surfaces of the sliprings should then be wiped with a dry grease-free cloth.

Bedding the Brushes

After fitting a new set of brushes, bed the brushes as follows (also



2 Spring scale
4 Looped leather strip
6 Top edge of brush holder

Fig. 8 Correct Method of Attaching the Spring Scale for Measuring Brush Pressure

bed brushes which have already been concaved).

Use medium-grain emery cloth (not coarser than 100 grains/cm^2). Lower the pressure fingers gently. Do not force the brushes on by hand.

In the case of motors operating in only one direction of rotation, bed the brushes by turning the rotor in the normal direction of rotation of the machine. When the brushes have been bedded, remove any remaining pieces of adhesive tape from the sliprings and blow out the carbon and abrasive dust.

Caution: Pumice stone should not be used for grinding, since the sliprings might become wavy if bedding were not carried out properly.

Measuring the Brush Pressure

Uniform pressure on all brushes is a prerequisite for uniform current loading. Measure the brush pressure as follows with the machine at standstill :

The measurements must be taken with care and preferably by two men (for checking the pressure fingers for correct position and for reading the spring scale). The brush pressure can be measured with the brushholder in the service position by means of a spring scale. The scales are available for various measuring ranges. Correct brush pressure :

Approx 200-300 gf/cm^2 (depending on type of holder)

Take out the brushes. For measuring the brush pressure, sling a leather tape around the outer contact face of the pressure finger, Figure 8.

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Siemens Circuit

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ELECTRICAL EQUIPMENT FOR OPEN CAST LIGNITE MINING

—G. RATNAM

In comparison to mineral coal, iron ore, etc., the lignite mining industry is still in its infancy. The large scale mining of lignite began only towards the second half of the last century, after the discovery of the briquetting process, which increased the heat value of the moisture-laden and ash-containing lignite from 1,800 kilo calories to 4,800 kilo calories (3,240 BTU to 8,440 BTU). However, it owes its rapid development to its being ideally suited to mines mechanisation, and it could be said that no other fuel could compete with lignite in this respect.

Practically all the lignite mined is obtained by open-cast or deep open-cast mining. Mechanisation has great influence on productivity, and in turn, causes a substantial reduction in labour employed. Unit costs are kept so low that, lignite, despite its low thermal value, can be economically substituted for coal. Due to the increasing demand for electrical power, the importance of lignite in the sphere of power generation cannot be over stressed.

The development of open-cast mining methods in Germany has undergone three stages of evolution. The first stage begins with the general increase in the demand for power between 1910 and 1914. During this time, big power stations have sprung up near the lignite mines. A rapid development of the exclusively, electrically operated open-cast mining machinery, as also the locomotives could be noticed upto 1930. The excavators used at this time had a maximum rating of 600 cubic metres per hour. D.C. locomotives of 900 mm gauge, service weights 60 tons and rating 680 kW with 1200 volts D.C. as the trolley wire voltage, were used in conveying the over burden and lignite. The depth limit from which the lignite could be stripped economically was approximately 60 to 70 metres.

In the year 1934, the excavator ratings were increased, and with it an increase in the locomotive ratings occurred. In Central Germany, the new excavators could strip and convey upto 3000 cubic metres per hour of lignite.

The locomotives were set on normal gauge of 1435 mm and their ratings increased to 1500 kW at 1500 volts D.C. with service weights of 100 to 150 tons. For the D.C. supply the mercury arc rectifiers replaced motor-generator sets. It was now possible to excavate economically up to a depth of 120 metres.

The increasing demand for lignite in Germany, with the attendant exploitation of coal seams at great depths, in even larger open cast mines in the 50s of the century coincides with the 3rd stage of development. Production ratings of mines per day have increased from 30,000 tons to over 100,000 tons. Mines to a depth of 300 metres have been planned and based on economical outputs, although the over burden to lignite ratio demanded that huge quantities of over burden be excavated, conveyed over a distance and dumped. At one time in Germany the economical limit of over burden to lignite ratio in case of open cast mines was 2.5 to 1, but this has been raised by intensive mechanisation and improved to as high as 7 to 1. The increase in outputs demanded the use of Bucket Wheel excavators, stacker/reclaimers, and spreaders for the removal of overburden and winning of lignite and also belt conveyor systems for conveying the material—of dimensions and ratio which the previous century could not have imagined as possible. The development of extra large excavators with service weights of 6000 tons and an installed electrical capacity of 10,000 kW and more, with a large number of motors controlled from a central position on the machine itself, would not have been possible by mechanical firms themselves without the

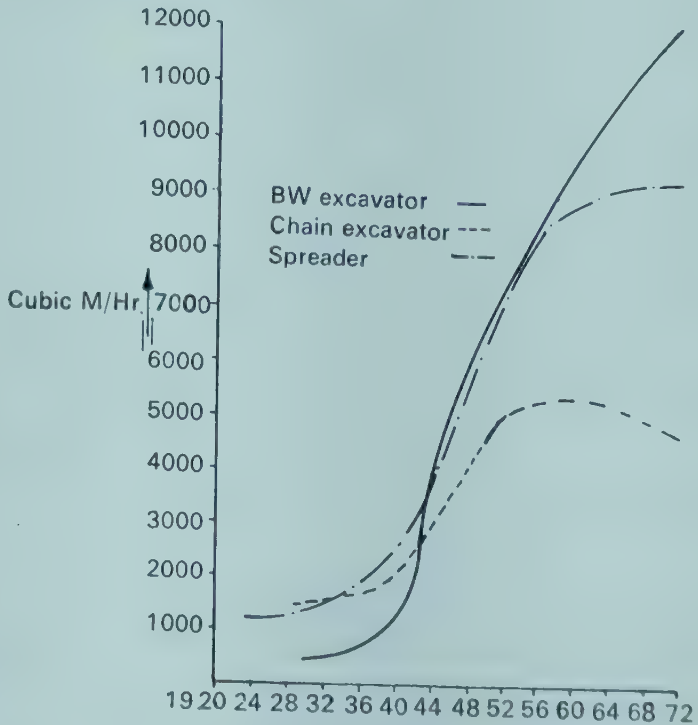


Fig. 1 Development of open cast mining machines

active help of the electrical Industry. Among the two types of Excavators developed, the Bucket Wheel excavator and the Bucket Chain excavator, the former, because of its many advantages and universality has become increasingly important, while the latter has become almost obsolete. The Bucket Wheel excavator ratings, on the other hand, have increased from 200 cubic metres to 7000 cubic meters per hour, Figure 1, and the weight of the machines from 100 tons to over 10,000 tons.

A giant Bucket Wheel excavator under construction today has a service weight of 13,000 tons and an installed electrical capacity of 15,000 KW, against 150 KW, which was the rating of the Bucket Wheel excavator built in 1933. To enable the huge volume of material to be handled, powerful stackers were developed together with the excavators. Present day stackers/reclaimers are capable of handling 32,000 tons of over burden/hour.

In 1956, a large brown coal or lignite deposit was opened out for the first time in our country at Neyveli near Madras. The area chosen for the first stage of the Integrated Neyveli Project, comprised of 5½ square miles north of the Cuddalore Vriddachalam Railway line. The Neyveli Lignite deposits are estimated to contain over 200 million tons of lignite.

For the winning of the lignite in Neyveli, methods similar to those prevalent in the modern open cast mines in Germany have been adopted. The ratio of over burden to lignite 3.2 to 1 at Neyveli was found very favourable, the lignite seam being 15 metres as against an overburden of 53.5 metres. Two large Bucket Wheel excavators have been used to dig the over burden in various steps from faces having a length of about 1,520 metres and to deliver this on to Belt Conveyors, which in turn transport the materials on to the spreader at the spot where the over burden is to be dumped. The exposed seam of lignite is stripped by smaller bucket wheel excavators and transported over Belt Conveyors to the Power Station, Fertiliser plant and finally to the Briquetting and Carbonisation Plant. After completion of the coal stripping, the reverse operation takes care that the over burden is dumped back.

The two small excavators have a bucket capacity each of 350 litres with a cutting height of 12 metres (39 ft.) and is able to excavate for about 5 metres

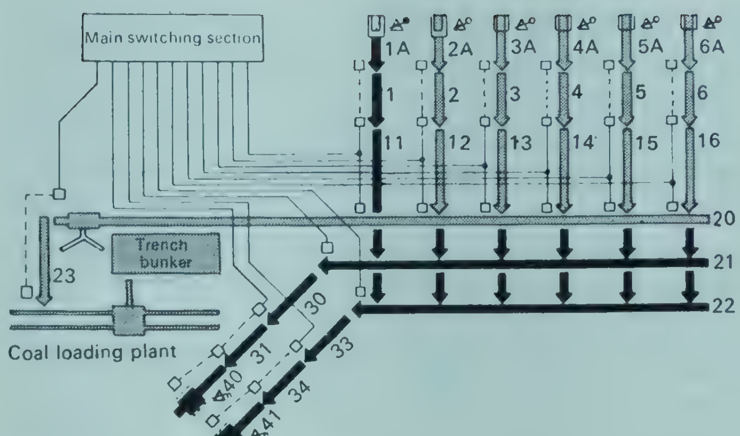


Fig. 2 Layout of a modern open cast mine in Kardia, Greece

(16 feet) below their ground level. They have an output of 920 cubic metres of solid material per hour. The larger excavator has a bucket capacity of 700 litres, with a cutting height of 20 metres (66 feet) and cutting depth of 3 metres (10 feet), with an output of 1,840 cubic metres of solid material per hour.

The spreaders working on the dump are crawler-mounted like the excavators and the material passes on them from the take-up belt to the discharge-belt, from where it is dumped or spread.

The most important and rather difficult and unique problem at Neyveli has been the control of artesian subsoil water which exists at high pressure below the lignite. Since the artesian water exerts an upward thrust of 6 to 8 tons per square foot on the base of the lignite, there was the risk of the water bursting through the lignite seam on the removal of over burden. To avoid this, about 48,000 gallons of water had to be pumped out per minute by means of 48 or more bore hole pumps—most of them around the area being worked out—to maintain the pressure of the water below lignite at a safe level. Here again, electricity has proved helpful. The 48 bore hole pumps, each with a capacity of 1,000 gallons per minute, driven by 150 KW squirrel cage motors, are supplied from 11 kV feeders with one 1500 KVA transformer, feeding 6 pumps.

The layout of a modern deep open cast mine in Greece shown diametrically in Figure 2 enables us to have a clear understanding of the magnitude of lignite mining operations. Stripping of the overburden is carried out in several steps with Bucket Wheel excava-

tors, working at different levels. The material reclaimed is discharged on to the mobile belts 1A to 6A through hopper cars. Belts 1A and 2A have a roller grid to intercept big lumps of material (overburden), allowing them to drop onto the conveyor belt from a lower level. The final excavator belts i.e. 11 to 16, have moving heads to put them to an appropriate length, thus enabling material to be discharged onto one of the three parallel collecting belts. The first belt line (belts 1A, 1 and 11) is intended to carry over burden. The rest of the belts convey the lignite. However, belts 12 to 16 are also able to discharge onto all three collecting belts, in case the need arises for all the belt conveyors to carry overburden.

The coal collecting belt (1510 m long) 20, runs along the bunker trench. Lignite may either be given for intermediate storage in the bunker, or loaded direct onto a coal train via belt 23. Separate trolley wires are provided in the bunker area to enable locomotives to be driven through the barney. Control is from a stationary control desk or from the mobile bunker excavator.

The coal can be loaded direct onto the train (without intermediate storage). Belt 20, via stacker discharges onto belt 23, and onto the coal wagons through intermediate and distribution belts.

From the two overburden collecting belts 21 and 22 the material is passed to the associated stacker through belts 30, 31, 40 or 33, 34, 41 and a tripper.

The Bucket Wheel excavator is a machine with many advantages and universal applicability. It offers a more favourable $\frac{\text{construction weight}}{\text{output} \times \text{cutting height}}$ ratio than that with the bucket chain excavator, which was an earlier development to keep investment costs lower. The Bucket Wheel excavator has three main sections: The **superstructure** with bucket wheel itself and the connecting belt to the main crawler mounted **under carriage** and the **loading belt** which disposes off the excavated material continuously, into rail wagons or conveyor belts through hopper cars. The bucket wheel, depending on its size, usually has 6 to 12 buckets with a cutting lip. The wheel is electrically driven at a certain definite speed—and has a capacity equal to the total volume of all buckets multiplied by the wheel speed per minute. Material cut by the bucket wheel passes through a series of belt conveyors from the moving plate on to the connecting belt, and via the intermediate belt on to the loading belt, each with a separate electrical drive. Figure 3 shows a medium size bucket wheel excavator of 700 litre capacity (1,840 cubic metres per hour) equipped with about 32 electric motors with a total rating of 1,800 KW. In addition to drives for the bucket wheel and belt conveyors on an excavator, the hoisting and slewing motions of the bucket wheel boom in the front and the loading belt boom at the rear, are also electrically driven.

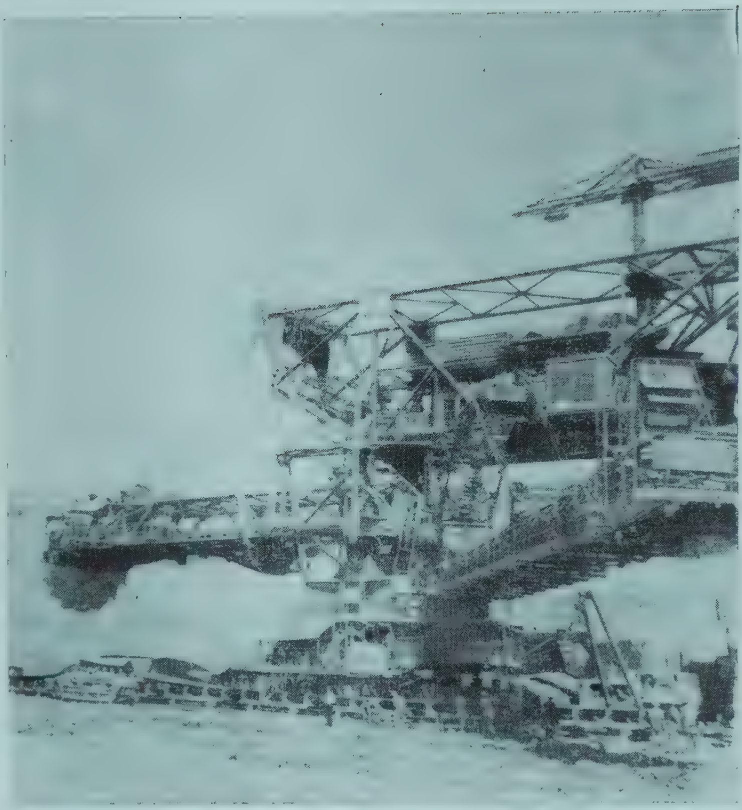


Fig. 3 A medium size Bucket Wheel Excavator

Today, to keep an economic conductor cross section of the trailing cable despite constantly increasing loads, supply voltages to the Bucket Wheel excavators, of 6 kV or 11 kV are generally used, while the giant machines require higher voltages upto 33 kV. Whereas the earliest open cast mining machines were fed from trolley wires by means of current collectors, now a-days, tough rubber insulated unarmoured cables, especially designed to suit open cast mining conditions are manufactured for voltages upto 33 kV. These flexible cables have to withstand severe mechanical stresses, as they are subject to constant winding and unwinding on the excavator cable drum during the

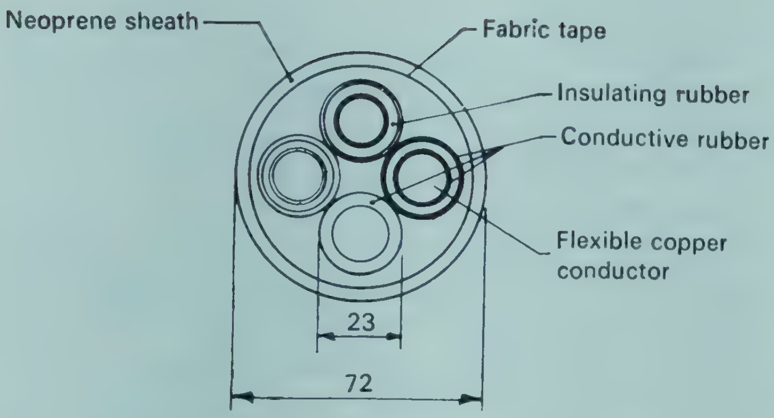


Fig. 4 Cross-section of 10 kV excavator drum cable 4×50 mm^2

working of the machine. Electrically, they have to be specially designed to prevent ozone formation which occurs at high field strength and destroys the cable insulation very quickly. To avoid dangerous field strengths, conductive rubber is used in the manufacture of this cable. Figure 4 shows a cross section of an " Ozonex " cable, which is very flexible and is protected by an outer sheath of wear-resistant neoprene, which has in addition, light resisting properties.

Figure 5 shows the electrical power distribution system on a Bucket Wheel excavator of 700 litre capacity with hopper cars feeding on to the belt conveyors. Identical machines have been commissioned a decade ago at Neyveli and are in successful operation since then.

Power is taken from the 11 kV feeder through the cable slip rings. The electrical equipment is in compliance with VDE 0168, " Regulations for Excavators, Conveyors and haulage systems in open cast Mining " compiled by the German Electro-Technical Commission. It might be pointed out here that no such regulations exist in other standards with special reference to open cast mining. A disconnecting switch panel is provided on the under carriage near the cable drum. To prevent inadvertent opening of the panel when the main C.B. is ' on ', special interlocking is provided, so that by opening the door of the disconnecting switch panel, the main circuit breaker is automatically tripped off. The excavator is provided with a 11 kV switchboard, with one 11/3.3 kV transformer and one 11 kV/400 Volts transformer, with corresponding 3.3 kV and 400 V switchboards. To keep the lighting, emergency release and circuit fault indication systems independent of the main transformer, the supply for these is drawn off before the main transformer, from the 11 kV bus and fed through a load break switch, to a 25 kVA transformer.

The bucket wheel drive consisting of one 650 KW totally-enclosed fan-cooled motor is supplied at 3.3 kV 50c/s. from the 800 kVA transformer. The slip ring design facilitates automatic starting, by means of contactors and time relays, which control the rotor resistor. The bucket wheel main drive has, in addition, an auxiliary drive, with a 120 KW motor, the supply of which is taken from the 400 volt bus. The different speeds of the bucket wheel are obtained by running the bucket wheel with main drive alone,

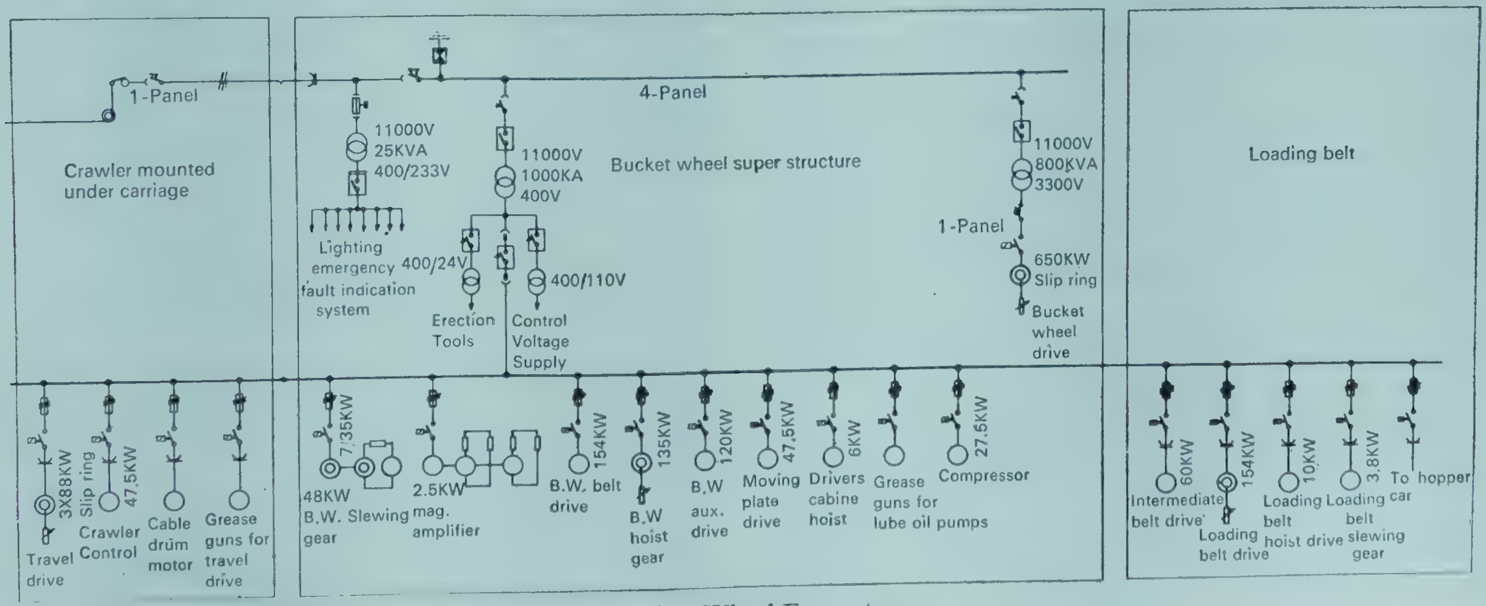


Fig. 5 Electrical power distribution of a 700 litre Bucket Wheel Excavator

with main drive and auxiliary drive running together, with auxiliary drive alone, and with the two drives in opposition. Repair and maintenance running of the bucket wheel is carried out with the help of the auxiliary motor. The travel gear of the excavator has 6 crawlers, driven by 3 slip ring motors, each with a rating of 88 KW and in the same type of enclosure as the bucket wheel motor. Normal contactor controlled resistors simplify the starting operations.

The drives for the belts, hoisting devices, and the Ward Leonard and MG set for the D.C. supply of the slewing gear are fed from the 400 volts switchgear. The belts are provided with three phase squirrel-cage motors and are started direct-on-line. Similarly, the moving plate drive, the hoisting and slewing drives of the loading belt, the driver's cabin hoist drive and auxiliary drives like grease guns lubricating oil pumps, compressor etc. are all squirrel cage motors and are started direct-on-line by means of contactors.

The bucket wheel hoist drive is provided with 135 KW slip ring motor and is started in 6 steps, automatically, by means of contactors and time relays. Special care has to be taken in the design of the control circuit to meet the requirements of the mechanical manufacturers. Control is carried out by means of a hand operated lever switch from the main control desk in the driver's cabin. Regenerative braking takes place practically upto zero speed, at which point the mechanical brakes act. This prevents a large scale wearing off, of the brake lining. A centrifugal switch built on the hoist motor shaft and adjusted to act at 10 per cent over speed, switches off the motor when this occurs. In case of such an emergency, the mechanical brake acts instantaneously. A direction control switch which is incorporated in the centrifugal switch, prevents the motor from running in a direction opposite to which it is intended, during the hoisting and lowering motions. It takes care that the brakes act quickly when this is the case. Regenerative braking prevents also a slackening of the wire ropes taking the weight of the bucket wheel, during the hoisting motion.

The slewing gear motor of the bucket wheel boom requires continuous speed control. For this purpose a D.C. shunt wound motor is used, fed with a variable armature voltage taken from a Ward Leonard MG set. Besides the continuous control of the

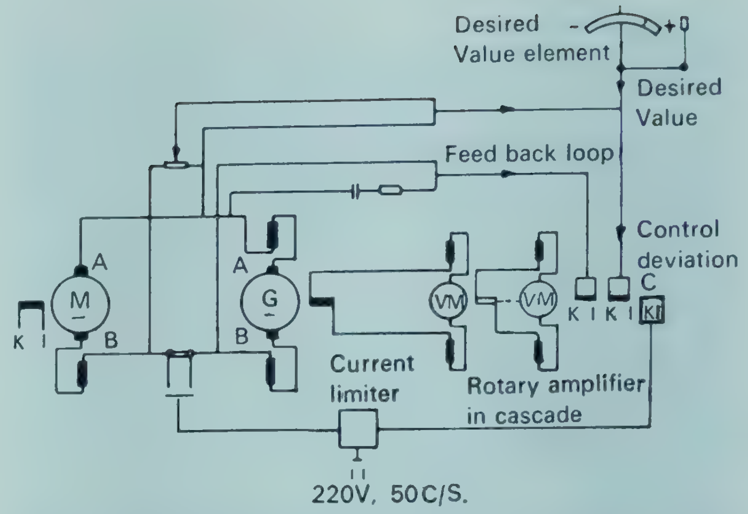


Fig. 6 Speed control of slewing motor with cascaded rotating amplifier (emf-circuit and armature current limiting)

motor speed, it is also necessary to limit the torque of the motor with regard to the stress of the mechanical gears, and other structural elements. For the same reason, the rates of acceleration for starting and deceleration for stopping of the drive, must be kept within well controlled limits. Modern feed back control methods offer very good solutions to meet such problems. The 700 litre bucket wheel excavator has, for example, a D.C. shunt wound motor of 7/35 KW capable of speed variation from 150 to 750 RPM as drive for the slewing gear mechanism. For control purposes, semi-automatic control is provided. It is so designed that a smooth starting as well as jerk free braking is possible. Figure 6 shows the basic arrangement for the speed control of slewing motor with cascaded rotating amplifier or Rapidyne*. The desired speed of the D.C. motor is kept practically independent of the load, the control system compensating automatically for any sudden load variation. The control limits the rate of acceleration, this ensuring smooth running upto speed independent of the action of the operator i.e. the control switch can be moved rapidly through the zero position without resulting in undue high acceleration. Reversing can be affected as quickly as desired. A current limiting circuit is provided to ensure that current surges are limited to a safe value, say, to two times the rated current at any time.

The desired speed is introduced into the control loop

*Rapidyne is the trade name of Siemens AG, Germany for cascaded rotary amplifier.

in the form of a D.C. reference voltage and is set by hand. The desired value is opposed by the actual value of the controlled condition which corresponds to the speed of the main drive motor. The comparison takes place in the amplifier. The actual value of the controlled condition is represented by the voltage drop across a voltage divider, which is proportional to the armature voltage of the control, or Ward Leonard generator. For shunt wound motors the voltage applied is approximately proportional to the speed obtained, so that it can be employed as an indication of the actual speed.

Rapidyne in its present day form is a D.C. amplifier consisting of a cascade circuit of 2 D.C. generators, in which one generator supplies the excitation for the other. The rotors of the machines are on the same shaft and the stators in the same frame. The amplifier has in addition 3 control windings, one for the desired value, the second for the actual value proportional to the speed and the third for the control value, which is the difference between the desired and the actual values.

A voltage corresponding to the difference between the reference and the actual value causes a current to flow through the control winding of the rotary amplifier. The field of the Ward Leonard generator is connected in series with the armature of the Rapidyne (main exciter) and is thus supplied with a variable voltage, proportional to the pre-desired value. Thus the deviation voltage between the actual and the desired values controls the amplifier which, in turn, controls the Ward Leonard generator in the direction of reducing the deviation. The control loop is adjusted with regard to the mechanical and electrical time constants, and with the use of one or several feed back loops, in such a manner, that stable performance is ensured, i.e. the loop should follow changes in the desired value with a quick, steady and non-oscillating response.

Electrical braking is provided by means of a voltage relay, which delays the action of the mechanical brake till the motor is brought practically to a standstill by the regenerating effect. The voltage relay is set, say, at 10 volts so that the mechanical brakes fall only after the generator voltage falls back from 230 volts to 10 volts.

The various drives of the Bucket Wheel excavator are controlled from a driver's cabin, so arranged on a control desk, that supervision becomes simple. To provide the operator with the best possible view of the Bucket Wheel the driver's cabin can be raised or lowered by means of its hoist drive. The control desk contains all the control switches and the alarm, or fault-indication panels, for the various drives. Further indication is provided in the switch room and it is possible to detect a fault very quickly. The easy-to-hand control levers and remote control, make the operation safe and quick. The direction of movement of the control switches is made to correspond to that of the respective motion. By means of a transmitter and receiver arrangement, it is possible to read accurately the crawler position on the control desk and thus, the control of the crawler-mounted travel drives is simplified.

For the electrical installation low voltage high power flexible cable with neoprene sheathing is used. This cable combines mechanical strength with flexibility and has proved its usefulness for open cast mining machines. The control voltage for the switchgear is taken from a separate control voltage transformer at 110 volts 50c/s. The galvanic separation from the power circuit prevents earth faults of one circuit affecting another. Limit switches to limit the angle of slewing, the hoist and lowering heights are provided for each drive. For the bucket wheel, hoist drive spindle operated limit switches are provided.

Emergency switches along lengths of the belts and at different points on the superstructure ensure opening of the main circuit breaker in case of an emergency. Interlocking between individual drives takes care of operation in a sequence. Time relays provide time lag between each operation of a set of drives. The interlocking switches provided near motors serve as emergency switches as well as a switch for local operation in a de-interlocked condition, to facilitate maintenance.

In principle the basic concept of power distribution on a Bucket Wheel excavator has remained unchanged through more than a decade. But rapid developments in thyristor fed D.C. drives, has enabled the electrical designers to use it when with increase in the machine ratings higher degree of reliability and control became a must. A brief mention of the

latest developments in this field will not be out of place.

A large Bucket Wheel excavator commissioned in 1971 with a daily capacity of 100,000 m^3 in Firmersdorf West Germany was the first machine to have a thyristor fed main travelling gear. The six groups of driving motors of the caterpillars consist each of two series connected D.C. motors of 130 KW rating. Each armature is fed from a thyristor convertor with field reversal. The thyristor convertor has a new control concept, ensuring exactly constant distribution of torques and imposing torque limitation on all motors. A mean value is formed from twelve individual actual values, providing a very smooth operation of the excavator. This reduces the stress on all mechanical parts particularly the travelling gear.

If a motor or a group of motors should fail, travel can be continued after a short time since the electronic equipment of each group can be disconnected individually without delay. The rest of the motors compensate the loss by developing a higher torque. The slewing gear of the superstructure provided with 4 Nos. 44 KW D.C. motors are fed through reversible four quadrant thyristor convertor for each motor. To keep the output as uniform as possible the slewing speed is regulated by a controller such that the total current of the three 430 KW 6 KV slip ring induction motor drives of the Bucket Wheel remains constant. The excavator driver's control of the slewing speed set point always has a priority. Even in the case of the belt conveyor at the loading end, the two 130 KW D.C. drive motors are fed from a reversible thyristor convertor.

The excavator has two optional main control stands and a loading control stand. The Excavator control stands handle about 300 indications and the loading control stand about 150 alarm and service indications. An electronic remote operating system in time multiplex fashion using longitudinal wires enables the transmission of 200 signals between super structure and under carriage through only 2 slip rings. The remote control system is connected to an electronic alarm annunciator system which enables the operator to take effective manual control steps under mormal service conditions as well as in the event of faults.

Quick and fault free communication is ensured between the machine and the main control station and other machines in the mine, through ultra high frequency 2 way trans-receiver sets. Carrier frequency communication through the 25 kV excavator trailing cable is used for connection to the general telephone system of the open cast mine and to report the excavator as ready for operation to the main control station. Carrier frequency is also used for interlocking the Bucket Wheel excavator with the belt conveyors carrying the material away from it.

A further improvement in the electrical distribution system is the provision of a 630 kV diesel generator set in the machine itself to cater to lighting and emergency power requirements, in case of a shut down in the main 25 kV power supply system.

The rapid development in mechanisation of open cast mines would not have been possible without belt conveyors which help the continuous transport of coal and overburden from the giant Bucket Wheel excavators to the Coal Storage Yard and over burden dumping areas. They ideally supplement the functions of modern mining equipment helping to fully utilise their capacity. Electrical engineering has played an important role since more than two decades, in solving the drive and control problems of belt conveyors and contributed to the achievement of the high standards of present day technology and the excellent reliability of conveyor systems. As against belt widths of 1200 mm in the 1950s today extra large belt conveyors have a width of 3000 mm and a transport capability of 37500 tons of material per hour. The length of individual belt conveyors upto 3 KM are not uncommon while the longest one commissioned in 1964 in Australia is 6.4 KM. Belt speeds of 5.2 m per second are more the rule today than an exception.

The main advantage of belt conveyors in comparison with other means of conveyance lies in its capacity to overcome gradients upto approximately 18°C. By using chain or lid belts these gradients may even be increased to more than 40°C. Simplicity and ease of operation are additional advantages while small demands are made on the bearing strengths

of the subsoil. Easy passage over and under roads, trenches and tracks is assured by means of simple structures. In addition, the possibility of parallel shifting, a distinct technical and economic advantage, leads to simplification in planning.

For the planning of electrical equipment of belt conveyors it is common practice to adopt the multi-motor drive in all cases, except for baffle and slewing belts. The conveyor belts have a head-end drive with two to four slip ring motors coupled together, or a head end drive unit plus a tail-end drive unit with one or two slip ring motors. Voltages upto 11 kV are not uncommon today to drive slip ring induction motors in the range 260 to 1500 KW. The energy distribution is carried out from a trans-switch unit with HT switchgear, transformer and LT switchgear on a common frame with skids to ensure mobility of the station. Because of the rigid conditions laid down by the mechanical firms to initiate steps to prevent and reduce wear on the belts during starting and running, increased demands on the electrical control are made. The starting torque has to be kept to a value equal to 1.3 times rated torque and starting must be free from jerks. Modern methods of control are based on the well-known formula for slip ring induction motors, $M=f(S/R)$ i.e. the torque is proportional directly to the slip ring and inversely to the rotor resistance. As the torque is kept constant during starting, the belt control device has the duty to control the rotor resistance in such a way as to keep the ratio S/R constant. To evaluate the slip the rotor voltage which is proportional to it is fed through a regulating transformer which is dependant on a transistor amplifier circuit. The actual value is compared with the fixed desired value in the amplifier circuit which in turn operates the relays controlling the rotor contactors. Each rotor resistance step has a transistor amplifier in its circuit. In view of the extreme requirements at no-load and overload it is not possible to fix the control device at one torque setting, in which case the acceleration of the belt at no-load will be too great. It must, therefore, be possible to choose two torque settings. This is possible by providing two different tappings on the rotor resistance, as a definite torque setting is inversely proportional to the resistance.

Present day control systems employ Electronic control—the rotor resistances are stepped by a binary code. Upto 30 different torque/speed curves may be selected from a theoretically possible wide range of curves, to cover a broad spectrum, without considerably increasing the number of rotor contactors. Electronic control is also used nowadays to ensure the regulated stoppage of Belt conveyors in a pre-specified time, independant of the loaded condition of the belt by adopting a D.C. braking system achieved with the help of thyristor convertors in the stator circuit of the drive motors.

The actual start up of the belt can be described as follows:

Each belt has a safety contactor in the circuit of which lie the contacts of the monitoring and safety devices i.e. emergency 'off', belt out of line, over current, brakes, slip and oil pressure. During the starting up process of the Belt conveyor, the safety contactor is actuated and if it holds on indicating a faultless safety circuit the start sequence is initiated. The safety contactor gives the signal for the tensioning motor and at the same time, the brakes of the drive motors released and the lubricating oil pumps switched on. As soon as the maximum pre-tension of the belt marked on the indicating instrument is achieved, the main drive motors are switched in on the stator side. Normally, the rotor resistance is adjusted to enable the motor to start against 0.6 times the rated torque.

However, in case of heavy duty when the Conveyor Belt is fully loaded, a relay switches automatically after a time interval the rotor resistance to 1.2 times the rated torque.

In order to utilise the rating of the Conveyor Belt drive to a maximum, it is necessary that the belt runs with a minimum pre-tension over the drum. A definite belt tension is necessary to protect the belt from damage due to over stresses. The belt tension has to be set for a certain value during starting and to a different value for normal running. This setting has to be maintained within certain limits despite certain load variations. A belt tensioning device must take care of all the above mentioned require-

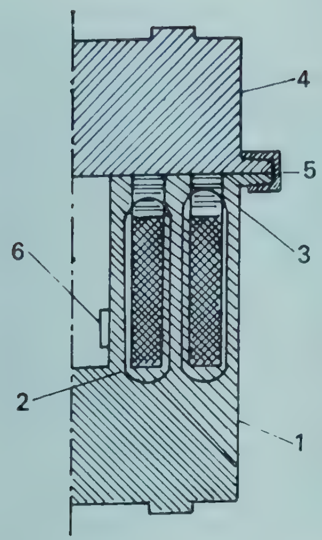


Fig. 7 Construction of a magnetoelastic pressure gauge

ments. Three setting values are chosen for starting, normal run maximum, normal run minimum. The belt tension is indicated in "t" and the tensioning device has two control circuits for "starting" and "normal running". The actual tensioning or detensioning is carried out by a drive motor on the carriage. For the measurement of the Belt tension and the transmission of the impulses, pressure-gauges are provided. The construction of a magneto-elastic pressure gauge is indicated in Figure 7. The body which takes the pressure (1) is designed to carry 2 to 10 kilograms per square mm at nominal load. The coils are laid in ring shaped slots (2). A few rings (3) are provided above them to close the magnetic field circuit. The machined faces of the body and the cover (4) are held together by a ring (5). In the central bore hole a temperature compensation is provided (6). The measured value of tension is transmitted via a Bridge circuit to the indicating instrument. By means of a built in maximum and minimum value transistor indicators in the instrument it is possible to control relays which give the signal for the tensioning and detensioning of the motor.

The control of the complete conveyor system including the Bucket Wheel excavator and spreader—taking into account the interlocking conditions is carried out as follows:

The sequence of starting begins at the spreader in a direction opposite to that of the conveyor, over the belt conveyors to the excavator. The switching off is carried out in the opposite direction. It is possible to run the belt conveyors individually for maintenance purposes. A de-interlocking switch is provided near each belt drive, and can be used as an emergency switch as well as a switch for local control of the motors. Before the starting up of the spreader an acoustic warning signal is sounded. Along the length of the belt a blink-system with red lights is also switched on. As the first belt on the spreader reaches 50 per cent of the normal speed, the "start-up" signal for the other belts is given. By means of the locally operated control stations the belts are now started one after the other. In case of an emergency, if one of the belts falls out, the conveyor system up to this belt is automatically stopped. A series of safety and monitoring devices are used to protect the operating personnel and the belt conveyors. Safety devices stop the plant and send an indication back. It is thus possible to stop the faulty belt as also the conveyor system up to this belt by pulling a wire rope running the complete length of the belt and connected to emergency switches at intermediate points.

After operation, the emergency switches are locked out and it is thus possible to find out the faulty point quickly. A blink-light signal is also set in operation to indicate this point. Emergency switches are additionally provided near the control points and they cause the HT circuit breakers to trip. The belts are further protected from going out of line by means of belt-monitoring devices which are fixed at distances of 75 metres along the length of the belt—on both sides. When the belt goes 20 c.m. out of its line, an optical indication lights up. If the belt goes out of line more than this, the belt drive is stopped automatically. A slip monitoring device keeps a constant watch over the slip of the belt on the belt drum. It takes care to give the command to the next belt for sequence operation and to release the mechanical brakes after the speed of the belt comes down to 20 per cent of its normal speed. This prevents dangerous tensioning of the belt. The belt drive motors have the normal over current and short circuit protection. The tensioning motor has additionally a temperature monitoring device because of its peculiar service conditions.

— S. J. D'SOUZA AND R. SACHDEVA

A great variety of industrial applications require a controlled voltage or current. These include motor speed control, electric welding and lighting control of installations. The common methods of varying the voltage or current supplied to a load are: (1) controlling the transformer secondary voltage or (2) inserting a controlling resistor in the output circuit. Neither of these methods is desirable. The first method requires expensive auxiliary equipment and the second results in high I^2R losses, and both require equipment which have moving parts and therefore subject to wear and tear. The development of thyristors has ushered in an era of highly efficient and relatively inexpensive control processes.

Thyristor Characteristics

Thyristors are controllable semiconductor diodes. When a negative voltage is applied to the anode, they behave like normal diodes: up to a certain voltage they block the current. On the other hand with positive applied voltage the thyristor has two characteristics: the forward characteristic and the forward blocking characteristic, according to whether the thyristor is fired or not.

The transition from the blocking (off) state to the conducting (on) state is initiated by firing (gate) pluses, with which the thyristor can be controlled externally.

On the other hand, transition from the conducting state to the blocking state takes place only when the load current passes through zero, or more precisely when the current drops below the so-called holding current. Accordingly, when direct voltage is applied,

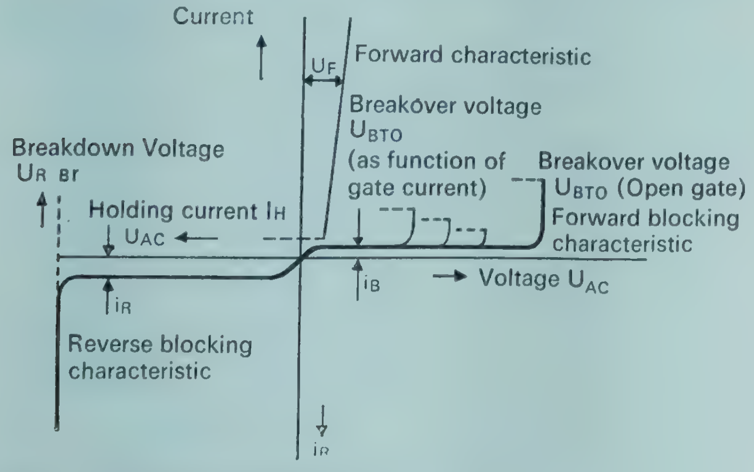


Fig. 1 Thyristor characteristics

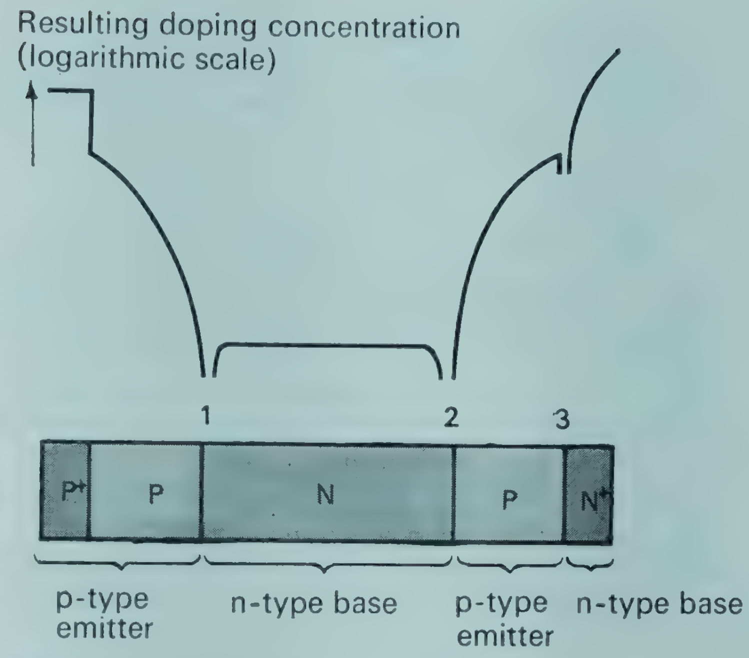


Fig. 2 Thyristor structure

a conducting thyristor, unlike a transistor, cannot be turned off again by control signals.

To understand the method of operation of the thyristor it is necessary to consider its layer structure. A disc of n-type silicon is generally used as basic material. Two p-type layers (p-type emitter and p-type base) and one strongly n-type (n-type emitter) are formed by the diffusing in of impurities, resulting in a four-layer structure. To facilitate contact-making the regions of the p-type emitter close to the surface are also strongly doped (P-region).

The two p-n junctions (1 and 2) adjacent to the n-type base are identical in their doping profile and consequently also in their blocking capability. Depending on their dimensions, the blocking capability of thyristors now in common use is between several hundred and several thousand volts.

The third p-n junction (3) is bounded by heavily doped regions and therefore generally has a negligibly small blocking capability (10 to 50 V) as compared with the p-n junctions 1 and 2.

When a direct voltage is applied to a thyristor, with negative polarity of the anode, space-charge regions are formed at the p-n junctions 1 and 3, i.e. the mobile charge carriers necessary for the flow of current are drawn away from these regions to the anode and cathode respectively. The current flow

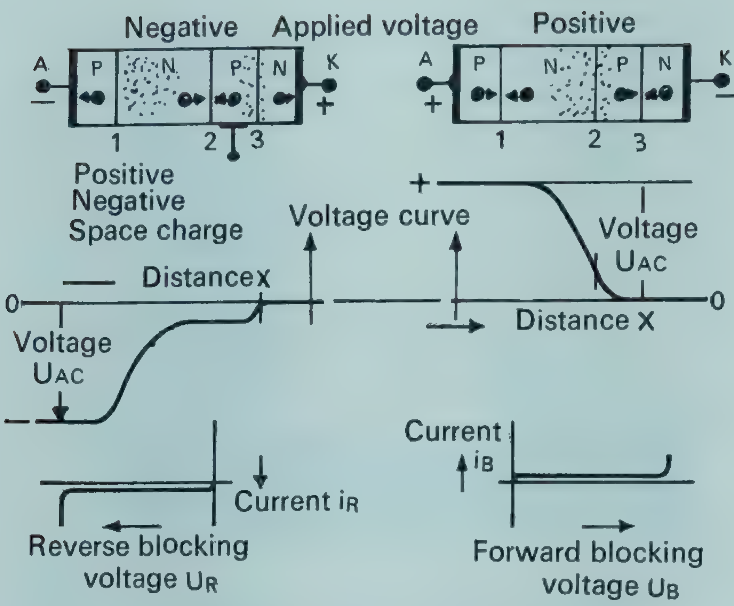


Fig. 3 Thyristor reverse and forward blocking states

is thus interrupted except for a very small reverse current (in the mA range). The thyristor blocks in the reverse direction.

When the polarity is reversed, a space-charge region is formed at the p-n junction 2, i.e. in this case also only a small reverse current can flow. The thyristor then blocks in the forward direction. As the blocking capabilities of the p-n junctions 1 and 2 are the same, a thyristor can block equally well in either direction, i.e. in the off-state it blocks both direct and alternating voltages. This applies to the whole working-temperature range from—40°C to +125°C.

The transition to the on-state is effected by means of a firing or gate pulse. Its action can best be understood if the thyristor is regarded as a combination of two transistors, a p-n-p and an n-p-n transistor.

When the thyristor is blocking in the positive direction (forward blocking characteristic) the whole voltage is applied across the middle p-n junction, i.e. in the equivalent diagram of the transistors the p-type collector of Tr.1 is negatively biased with respect to the emitter 1 and the n-type collector of Tr. 2 is positively biased with respect to the n-type emitter 2. If now a short current pulse is injected through the gate electrode, i.e. the p-type base 2, the holes passing from the p-type base to the n-type emitter 2 (cathode) raise the base potential somewhat (as with a p-n diode in the forward direction) and trigger a considerably larger injection of electrons, which are taken up almost without loss by the positive collector 2. This collector current, now amplified with respect to the original gate current, controls the top transistor via the n-type base 1 and leads to a further amplified injection of holes of the p-type emitter 1 (anode).The injected positive charge carriers again pass to the base 2 via the collector 1 and the cycle continues with increasing effect. While the current increases like an avalanche, the space-charge regions at the collectors (middle p-n junction) become completely swamped with carriers; the voltage must then collapse and the middle region fills up again until a new state of equilibrium, i.e. a working point on the forward characteristic, is reached. After the gate pulse has ceased, the thyristor remains in the on-state. It cannot again block until the current in the main circuit has dropped below the holding current and after the elapse of a so called turn-off time, which is necessary to allow the carrier inundation of the middle p-n junction to disappear.

Thyristors are particularly suitable for switching alternating currents, because in this case the current periodically passes through zero.

Action of the short-circuit emitter: In addition to the method of firing by gate pulses shown in Figure 4, there is the possibility that the thyristor may fire without any external control pulse if the rate of rise of the forward blocking voltage du/dt is too high.

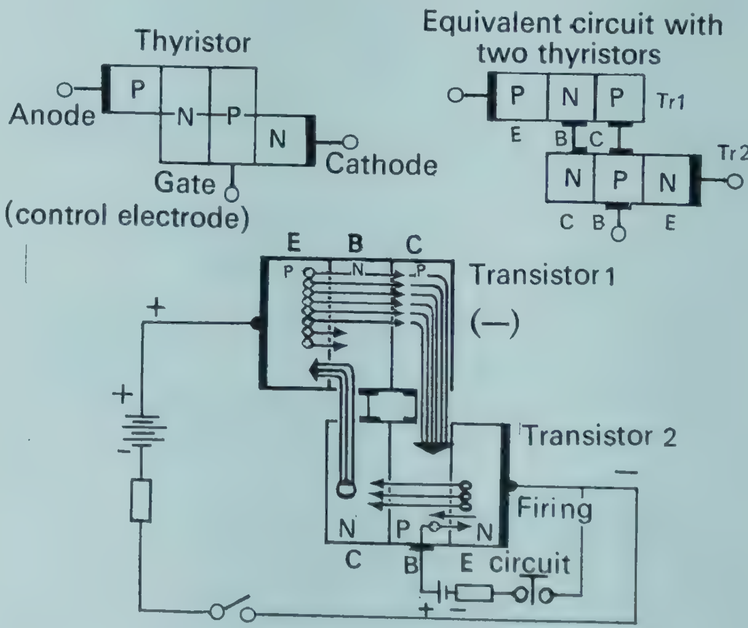


Fig. 4 Firing mechanism of a thyristor

This is due to capacitive currents, which occur as the barrier layer of the middle p-n junction is built up. The flow is in the same direction as the gate pulses and consequently have the same effect, Figure 5.

This firing as a result of too rapid a rate of rise du/dt is undesirable and is dangerous for the thyristor. To prevent this, modern thyristors are equipped with integrated, usually circular emitter, shunts R_N uniformly distributed over the whole emitter surface. Part of the capacitive current flows through them, bypassing the direct path through the emitter p-n junction, to the cathode and can therefore not act as a control current. The path through the emitter is avoided because for this the threshold voltage of the p-n junction would have to be exceeded.

With the transistor, the current (collector current) is transported by only one kind of carrier, as there is only one emitter: For this reason the collector current needs a continuous controlling base current so that it can be maintained. The transistor is thus continuously controllable and in particular it can be switched off via the base current. It is therefore particularly good for the control and switching of direct currents. One may therefore call the transistor a D.C. switch and the thyristor an A.C. switch. By supplementary means by which the current can be forced to zero, the thyristor may of course also be used as a switch in D.C. circuits. It is thus a controllable valve with a wide range of application for control and regulation as well as for all kinds of conversion of electrical energy, Figure 6.

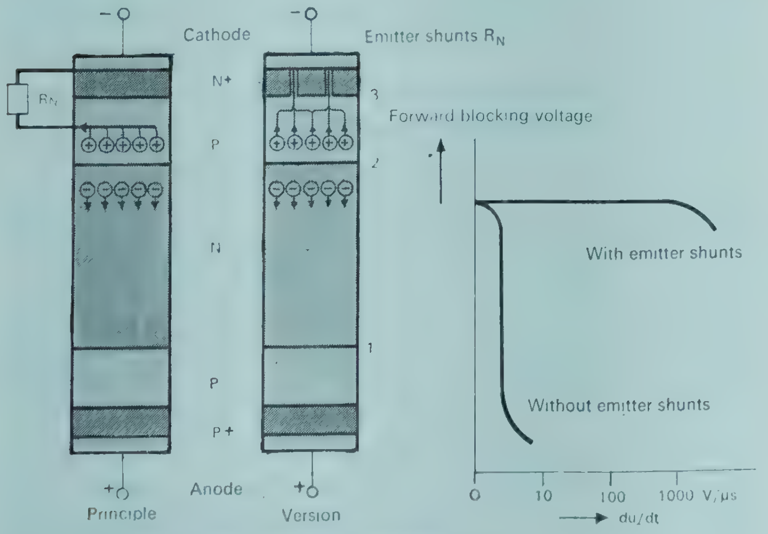


Fig. 5 Action of the short-circuit emitter

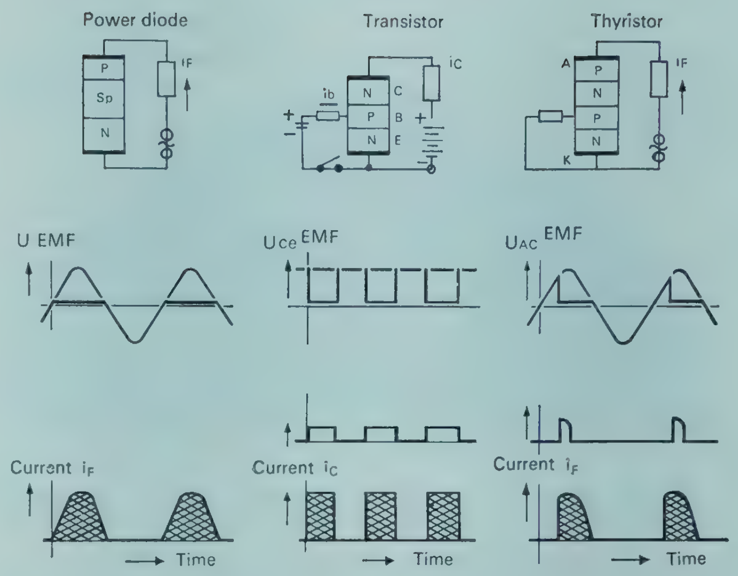


Fig. 6 Diode transistor and thyristor switching functions

Figure 7 shows a cross-section through the active element, all three p-n junctions of which have been produced by diffusing in impurities (full diffusion technique). To protect the silicon disc from mechanical damage it is alloyed on to a molybdenum carrier plate, which also acts as anode connection. The contact on the cathode side is made by vapour deposition of an electrode, as is also the centrally arranged gate electrode. The p-n junctions of high blocking capability come to the surface at the side of the silicon edge. This region must be treated with particular care during manufacture; amongst other things it is protected by a special varnish to ensure a long-term electric strength of the element under all operating conditions.

In addition to reverse and forward characteristics, a number of other characteristics are of importance for the practical application of thyristors. These include the di/dt behaviour. Figure 8 shows clearly that when a thyristor is turned off by a gate pulse, initially only a small area adjacent to the gate electrode becomes conducting. The extension of this area proceeds with a radial velocity of about 0.05 to 0.1 mm/s. If the load current increases too quickly in relation to the velocity of this extension, high turn-on losses occur in the silicon, which eventually damage the element.

For this reason, in thyristor circuits the rate of rise of the current di/dt should never exceed the values stated by the thyristor manufacturer. Normally, for thyristors now in continuous service di/dt values

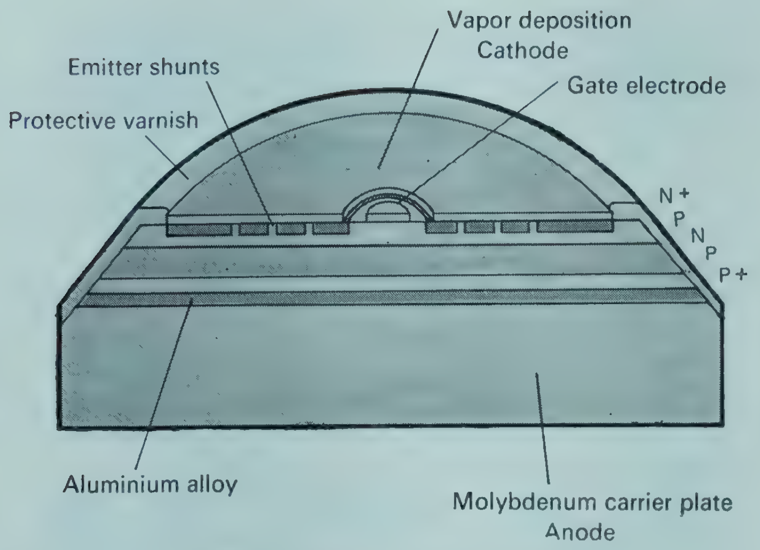


Fig. 7 Cross-section through a thyristor element

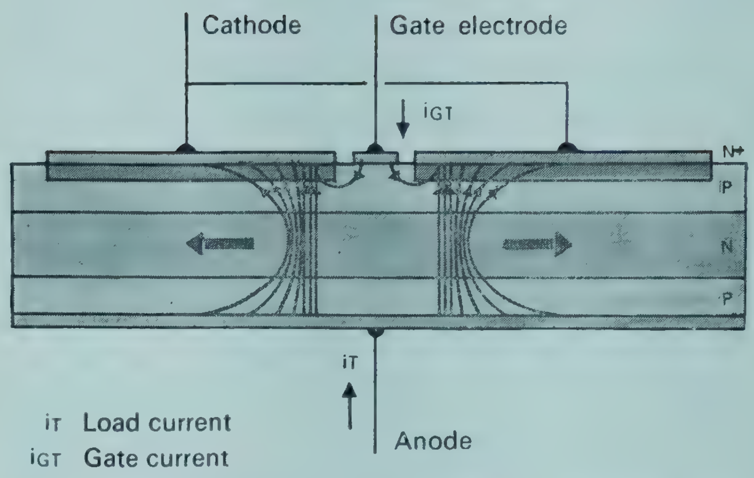


Fig. 8 Current distribution in the thyristor immediately after switching on

between 50 and 200 A/µs are permissible. For special purposes there are also thyristors with specially shaped gate electrodes, with which higher di/dt values are permissible. These can work at frequencies up to about 10 kHz. The frequency range above this will presumably for some time remain the province of the transistor.

With ordinary commercial thyristors the actual thyristor element, the wafer, is encapsulated as protection against external influences. The capsule must be designed so that connections can be easily attached and the heat due to losses in the wafer is adequately dissipated.

Thyristors for small and medium powers (continuous currents up to 300A) are generally cooled on one side only. Threaded-stud and flat-base versions are typical.

The current is fed to the cathode side by cable. The copper base is the anode terminal and at the same time the connection to the heat sink.

For the internal contacts of thyristors, i.e. between the wafer and the cable connection and between the wafer and the copper base, with large-area elements the compression bonding principle has proved satisfactory. It avoids thermal stresses (due to the different coefficients of thermal expansion of silicon and copper) at the points of connection between the wafer and the enclosure since the points of connection are not soldered together, but are only pressed together under high pressure. On changes of temperature the parts of the connection can slide over one another without the electrical contact and the thermal resistance of the cells being impaired.

Thyristors for the highest continuous currents have to be cooled on both sides. The disc form of cell is typical. The pressure necessary for contact making must be provided by the heat sink. Depending on the size of the element a pressure up to 10,000 N may be necessary. The cooling medium may be air or a liquid (oil or water).

Typical Applications

Half Wave Controlled Rectifier Circuit

The simplest controlled rectifier circuit consists of a single thyristor connected to a resistive load, Figure 9. The circuit for applying gating pulses to the thyristor is not shown.

The thyristor conducts when the voltage across it is positive typically (during the intervals of ac voltage from wt=0 to π, 2 π to 3π etc. Figure 10(a). In addition, the thyristor must receive a gating pulse—applied at a firing angle. This angle α is measured from the angle that produces the largest load voltage, in this case from wt=0, 2π etc.

The waveforms of the load voltage U_L for two values of α are shown in Figures 10(b) and 10(c). The thyristor conducts from α to π and then cuts off because the line voltage goes negative. On being fired again at an angle $2\pi + \alpha$, it conducts and this cycle is repeated. The time during which the thyristor is ON is called the conduction angle. During the conduction intervals the load voltage is nearly equal to the line voltage. The small difference between the two is because of the voltage drop across the thyristor

As the value of α is shifted by the control circuitry from zero to π, the average load voltage decreases as well.

Mathematically, this average voltage is given by
$U_{av} = 0.225\ U_o\ 1 + \cos\alpha$
where U_o = rms line voltage
It should be noticed that Uav decreases to zero as α approaches II.

Thyristor Power Control Circuits

Two simple circuits for controlling the power to a load are given in Figures 11(a) and (b). Resistor R serves to limit the peak gate current to less than 2A. In (a) when S is closed the thyristor is fired as a result of the flow of gate current. The voltage across the thyristor drops to a low value (about 1V) and hence prevents a further flow of gate current. Thus current flows in the gate only long enough to fire the thyristor.

The diode is added to prevent reverse gate current. Part (b) shows an arrangement for controlling both halves of an ac voltage. In this case two thyristors are connected back to back. When line A is positive, a small current flows through D2, switch S, resistor R, and from the cathode of Th1 to C and B. This gate current quickly fires Th1 causing large current flow through the thyristor and load. Since A to C voltage drops to a low value the gate current stops.

In the next half cycle when line B is positive, gate current flows first through D_1, resistor R, switch S and the gate of Th2 to A. This fires Th2 and current now flows through the load, through Th2 to A. The resulting low voltage across Th2 brings the gate current to a stop. The waveform for an arbitrary firing angle α is shown in Figure 12.

As is perhaps obvious by now, a single thyristor acts as a faster solid state equivalent of a contact that

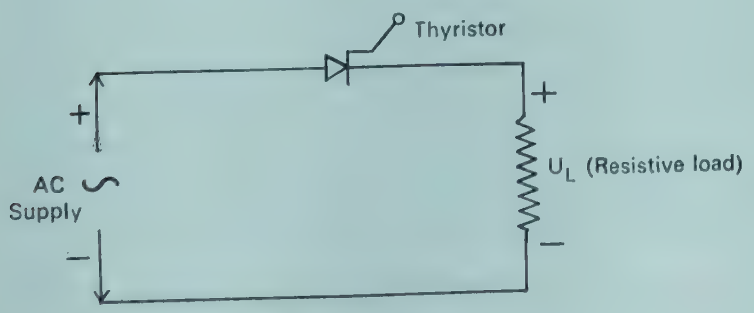


Fig. 9 Half-wave controlled rectifier

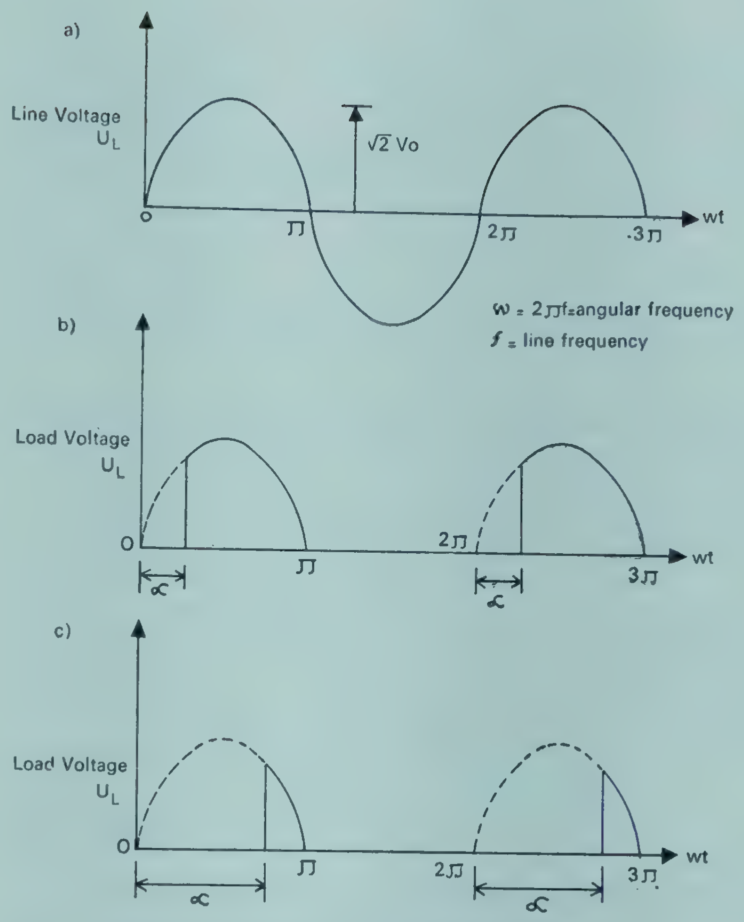


Fig. 10 Operation of half-wave controlled rectifier

closes and opens. A flow of DC gate current may be provided during the number of cycles for which the load is to receive AC power. With gate current applied, the thyristor is conducting and is equivalent to the closed state of the contact. The off state without gate current is analogous to the contact being open.

Control Circuit for Thyristor Firing

Since a thyristor is usually fired by a pulse of gate current, a circuit is needed that can delay and control the instant of occurrence of the pulse. One means of obtaining such short time pulses is to use a unijunction transistor (UJT).

The UJT, symbol given in Figure 13(a), is a three terminal switching device used to apply a sudden pulse of power to some associated circuitry (like the gate of a thyristor). If an increasing voltage is applied between the emitter E and base B_1, no current flows through the UJT until this voltage reaches a threshold level VE. When this threshold is exceeded, the E to B_1, resistance falls to a low value and thereby results in large current flow.

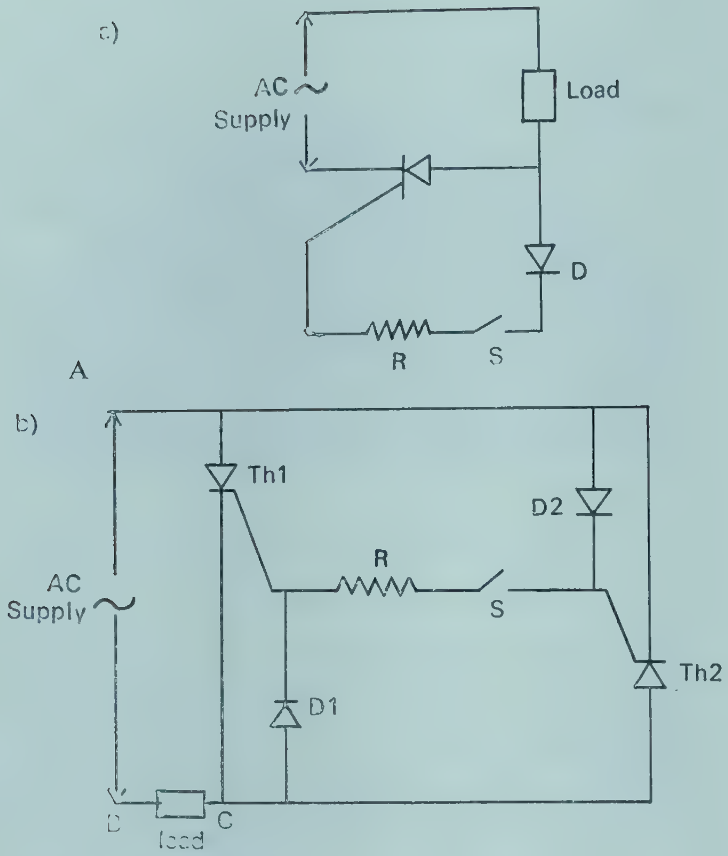


Fig. 11 The thyristor in simple AC circuits

A circuit using a UJT to fire a thyristor is shown in Figure 13(b). As long as switch S is open, no part of the UJT circuit receives any voltage. When S is closed, the capacitor C_1 begins to charge upto the voltage V_Z at a rate determined by the time constant R_1 C_1. When the voltage across C_1 exceeds V_E, the UJT is triggered. The E to B_1, resistance falls to a low value and hence permits a sudden surge of current as C_1 discharges through the UJT and the external resistance R3. A part of this discharge becomes a pulse of gate current sufficient to fire the thyristor. As soon as the thyristor begins conducting, the switch is opened so that C_1 does not charge up

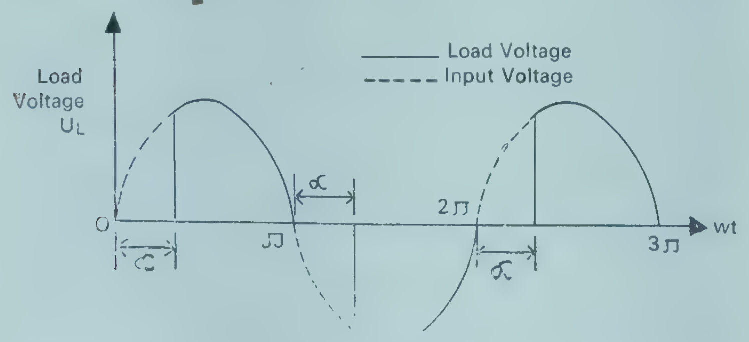


Fig. 12 Waveform for circuit of Fig. 11

again during the same AC cycle. At the start of the next cycle, S is closed and this sequence is repeated. The waveform for the charging and discharging cycle is given in Figure 13(c). Since resistance R_1 determines the rate of charging of C_1 it may be varied to change the phase angle at which the gate pulse occurs to fire the thyristor.

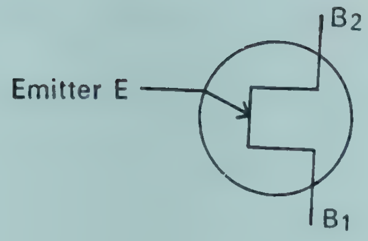
The above triggering scheme is so basic that it forms the building block of almost all thyristor control circuitry. In practical circuits, the switch S is replaced by electronic components. The mechanical model has been used to simplify understanding.

Figure 14 illustrates a circuit which uses this scheme. This circuit is in fact the half wave controlled rectifier of Figure 9 but with the added control circuit. The battery and switch of Figure 13(b) have been replaced by diode D and a Zener Diode biased in its breakdown region. (The Zener Diode when used in this mode maintains a fixed voltage V_Z across it as long as there is current flow through it). When terminal A is positive, the increasing voltage passes through D and R_5 but the potential at B is limited to a value V_Z across the Zener Diode. The voltage across capacitor C_1 increases towards V_Z until it is discharged through the UJT and R_3 to fire the thyristor (as is described above). Since all the supply voltage now is applied across the load (except for about 1V across the thyristor), the voltage between B and C also has disappeared. This ensures that the discharged C_1 does not recharge within the same cycle. When the supply voltage reverses and terminal C is positive, the thyristor is turned off. The current in the control circuit is also inhibited because of diode D. A similar operation takes place in subsequent cycles.

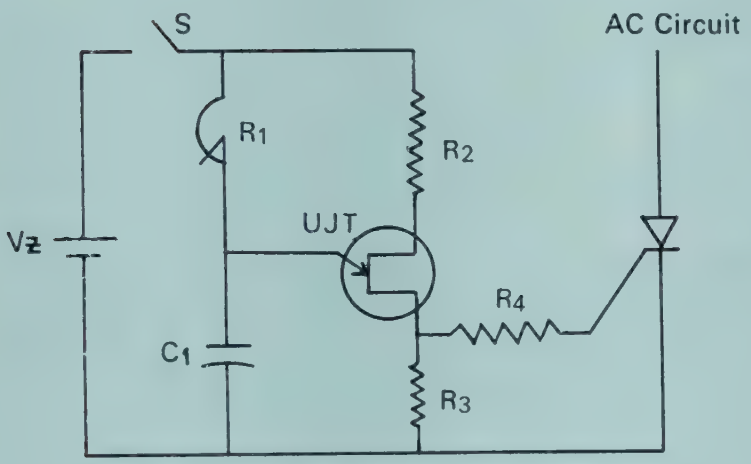
The Light Dimmer

An important application, the light dimmer is shown in Figure 15. In each half cycle the rising AC voltage (applied through either diode A or B) charges capacitor C_1 through the variable resistance R_1. As voltage across C_1 increases it charges the larger capacitor C_2 more slowly. C_2 then discharges through R3 into the gate and hence fires the thyristor. The lamps may be dimmed by varying R_1.

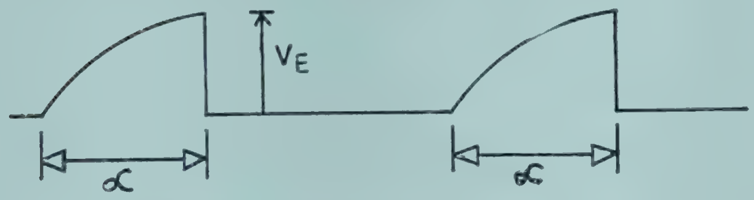
To facilitate understanding let us consider three illustrative cases:



a) UJT circuit Symbol



b) Control circuit for thyristor firing



c) charging and discharging cycle at capacitor C,

Fig. 13 (a) UJT—Circuit symbol (b) Control circuit for thyristor firing (c) Charging and discharging cycle of capacitor C1

(a) If R_1 is turned clockwise to nearly zero ohms, C_1 and C_2 charge quickly so that the thyristor is fired near the start of each half cycle. This means that the lamps receive nearly full line voltage and hence glow brightly.

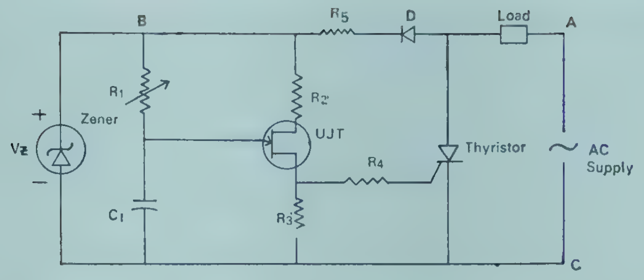


Fig. 14 A practical circuit—half-wave controlled rectifier

(b) If R_1 is set midway, C_2 discharges through R_3 and the thyristor near the middle of each half cycle. The average load voltage as compared to case (a) is consequently reduced and hence the lamps glow less brightly.

(c) With R_1 turned anticlockwise to the greatest resistance, C_1 charges so slowly that the thyristor is fired very late in each half cycle. This results in the lamps glowing dimly.

Conclusion

The thyristor as a power electronic component is finding a wide variety of uses in the electronics industry.

The basic examples given serve to illustrate how the thyristor can be adapted by the engineer for use in industrial applications.

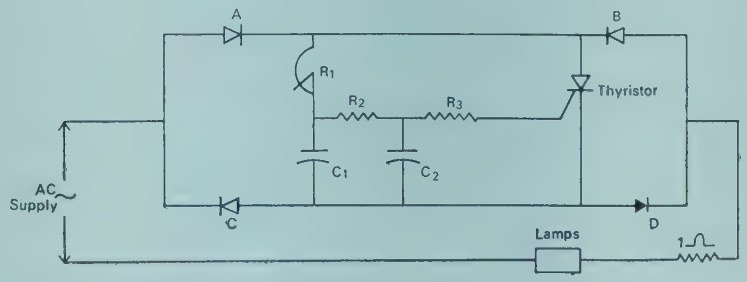


Fig. 15 The light dimmer

CONTROL SYSTEMS ENGINEERING WITH SIMATIC N

—S. K. BHATIA

There is an ever increasing demand for power, steel, fertilizers, basic chemicals, petroleum products, cement, sugar and a host of other industrial products one can think of. It is universally found that larger plants with single stranded systems are more economical from capital cost and operational point of view than the plant concept employed till recently which provided for several low-capacity units operating in parallel. The impact of this change in philosophy and the challenge it poses to the control engineers is widespread. This calls for a more comprehensive closed loop and open loop control technique. This article focuses only on the open loop control engineering.

For continuous Process Plants This Means

(1) To use more comprehensive interlocking devices to protect the drives and the plant machinery from faulty operation and disorders in the plant.

(2) Also to use a more comprehensive monitoring system for early detection and signalling of faults and disorders with the aim that down-time should be reduced to a minimum. The down-time of a large plant is a very costly affair resulting in large production losses.

(3) To use more and more automatic rather than manual control under critical process states e.g. start-up, shut-down and during disorders. The reliability of manual operation under such process states depends highly on the operators and cannot be taken for granted.

(4) To shift more and more the contact between the plant and the operators to the centralised control room rather than the field. In this way manual interventions into the process can be coordinated better and carried out faster. This gives the operators a clear picture of the process state and makes their work less strenuous.

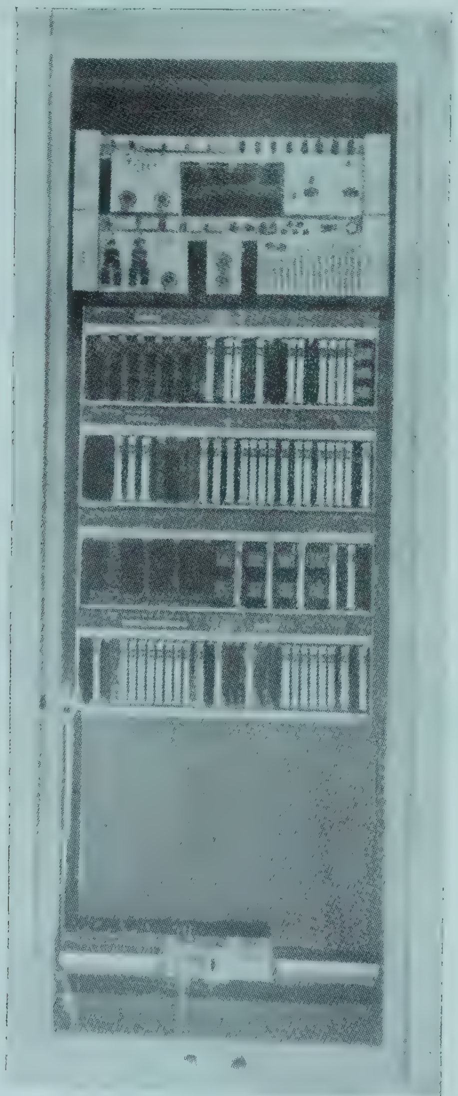


Fig. 1 A typical SIMATIC N control panel

For Batch process plants, in addition, the product quality is improved by automatic programme control system which controls the sequence, the reaction time, etc. more accurately than the operators could. All the above logic switching functions could be achieved by the 'Relay Technology' using conventional relays in conjunction with appropriate time delay relays. Or they could be done by the 'SIMATIC Technology' i.e. purely statically using appropriate combinations of AND, OR, NOT operations in conjunction with time functions. The control systems which become more and more complicated promote the use of SIMATIC technology even if the switching speeds and the number of switching cycles can be handled by relay technology.

The reasons are as follows:

(a) High degree of reliability even in a corrosive chemical atmosphere.

(b) Low space requirements and

(c) Use of functional components which handle complex switching functions.

Looking at the control problem in a broader perspective, we arrive at the following picture:

The input quantities are sensed and measured by transducers and primary input sensors of various

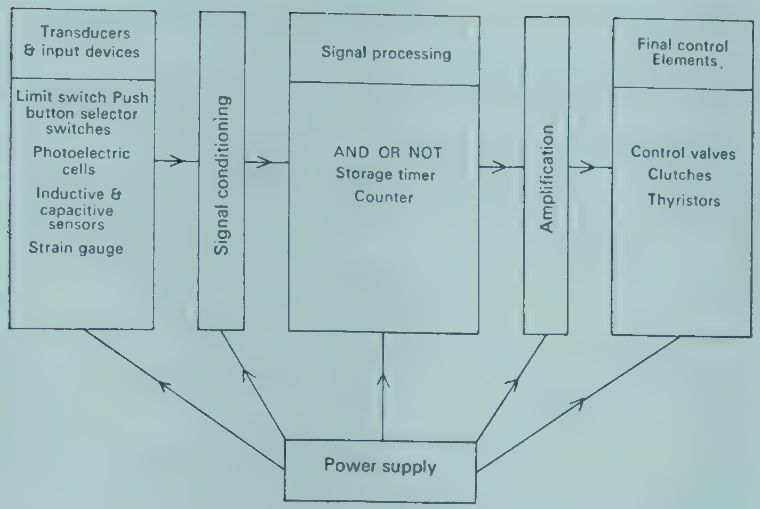


Fig. 2

types, Figure 2. Limit switches and signalling contacts are used to detect the position of mechanical elements.

Not only can all physical quantities be used as input variables but also numbers in coded digital form.

Basic Functions

SIMATIC is built up on the basic logical operations AND, OR and NOT. Each logical operation of a binary signal can be based on a combination of these three functions in conjunctions with storage devices—memory. In principle it is immaterial whether these operations are realised by means of relays, switches or as is being done to an increasing degree by the gates of SIMATIC.

1. AND

Figure 3 illustrates the AND operation. Relay X picks up and produces an output signal at its normally open contact 'X' only when both contacts 'a' AND 'b' are closed.

The AND gate in SIMATIC consequently has a signal at output X only when both inputs 'a' and 'b' have signals. This is also expressed in the Truth Table. In accordance with the basic rules of switching algebra, a 'dot' between 'a' and 'b' denotes the AND operation e.g. Fx=a.b., Figure 3.

2. OR

The OR operation is performed by contacts in parallel in conventional relay systems. Relay X in Figure 4 picks up and produces an output signal at its normally open contact X when one of the contacts 'a' OR 'b' is closed.

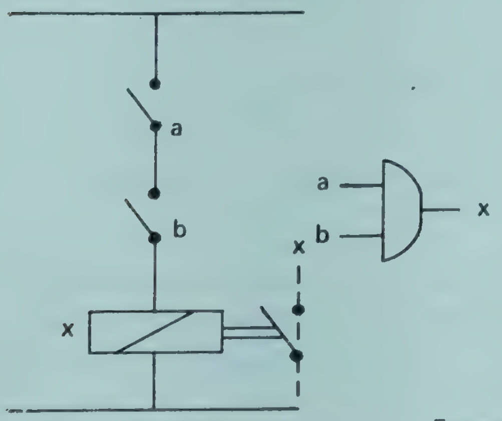
The OR gate in SIMATIC consequently has a signal at output X when one of the inputs 'a' or 'b' has a signal. This is also expressed in the Truth Table. As per the rules of switching algebra a '+' between 'a' and 'b' denotes the OR operation e.g. $F_X=a+b$.

3. NOT

In the case of NOT operation, also known as inversion or negation, the output is always the inverse of its input. In relay circuits, the NOT operation is performed by the arrangement shown in Figure 5. The output of the circuit, in this case the normally closed contact of the relay is 'I' when 'a' is '0' and vice versa.

In SIMATIC the NOT operation is performed by the NOT gate. The output of this element has a signal when there is no signal at the input and vice versa. In terms of switching algebra $F_X=\bar{a}$.

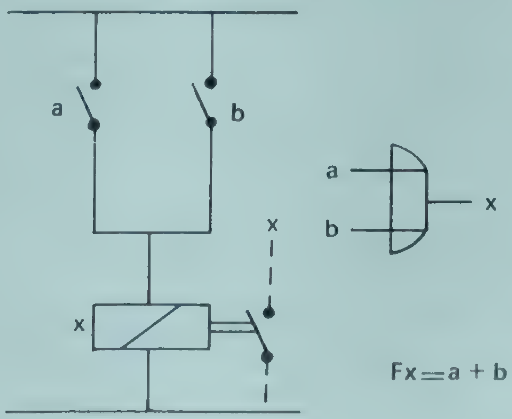
All other more sophisticated logical functions required for the processing of binary signals can be performed by the three operations AND, OR and NOT described above.



a	b	x
0	0	0
1	0	0
0	1	0
1	1	1

Fx = a . b

Fig. 3



a	b	x
0	0	0
1	0	1
0	1	1
1	1	1

Fx = a + b

Fig. 4

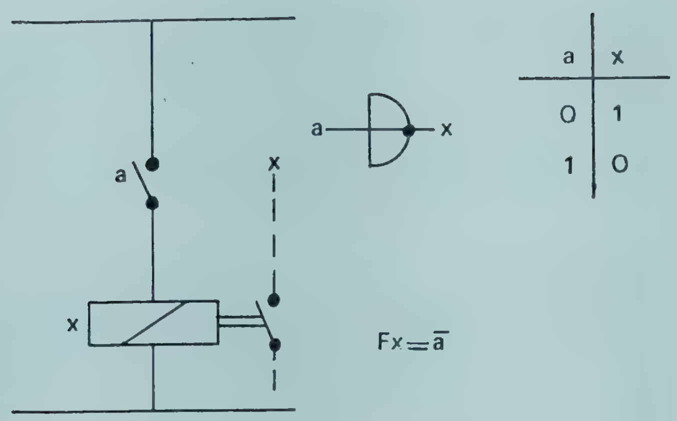


Fig. 5

In binary systems the number of possible combinations increases very rapidly with the number of input variables, in Figure 6 all the combinations between the output X of a binary system and two inputs A and B are tabulated. Both variables can take the value '0' or '1' independent of each other so that $2^2=4$ combinations are possible at the input. Independent of this the output X can also take the values '0' or '1'. Therefore, there are totally $(4)^2=16$ possible combinations between the two inputs and the output. Out of these, the combinations 1 and 16 are meaningless as the output shows no dependance on the input and has continuously '1' or '0' signal. For the combinations 4, 6, 11 and 13 the output is dependant on only one input variable and hence is meaningless for a system with two inputs. The combinations 2 and 8 are the well-known functions AND and OR and the combinations 9 and 15 their inverse forms i.e. NAND and NOR.

As the number of possible combinations is dependant on the number of input variables and increases at the rate of 2^{2^n}. A system with 3 inputs offers 256 possibilities and a system with, for example 10 inputs, has practically an infinite number of combinations. However, systems with more than 10 inputs are still rare in practice.

4. Memory Devices

The fourth basic function in processing of binary signals is performed by the memory or storage devices. Storages can retain binary signals for a definite or indefinite period of time.

a	0	1	0	1	Name	Function
b	0	0	1	1		
1	0	0	0	0	Never	X=0
2	0	0	0	1	AND (Conjunction)	X=A.B.
3	0	0	1	0	Inhibition	X=$\overline{A}$.B.
4	0	0	1	1	Identical (to B)	X=B
5	0	1	0	0	Inhibition	X=A.$\overline{B}$
6	0	1	0	1	Indentical (to A)	X=A
7	0	1	1	0	Exclusive OR (Antivalence)	X=A.$\overline{B}$+$\overline{A}$.B
8	0	1	1	1	OR (Disjunction)	X=A+B
9	1	0	0	0	NOR	X=$\overline{A+B}$
10	1	0	0	1	Equivalence	X=$\overline{A}$.$\overline{B}$+A.B
11	1	0	1	0	Not (Negation)	X=$\overline{A}$
12	1	0	1	1	Implication	X=$\overline{A}$+B
13	1	1	0	0	NOT (Negation)	X=$\overline{B}$
14	1	1	0	1	Implication	X=A+$\overline{B}$
15	1	1	1	0	NAND	X=$\overline{A.B}$
16	1	1	1	1	Always	X=1

Fig. 6

(a) The classical example of a storage capable of retaining its information for an indefinite period is the conventional relay with maintaining contacts. Storages are 'set' and 'cleared'. The relay type storage device is set by the pulse produced when contact 'a' is closed. Relay X then picks up and holds itself via its normally open contact 'X' and the normally closed contact 'b'.

This state is maintained indefinitely until the relay is caused to drop out by opening the normally closed contact 'b'. X output is referred to as the set and $\overline{X}$ clear.

In SIMATIC there are different types of storage devices. The storage device most common in use is the bi-stable flip-flop which also finds application in computers. Also, there are magnetic drum, magnetic core and magnetic disc storages which unite thousands of such static

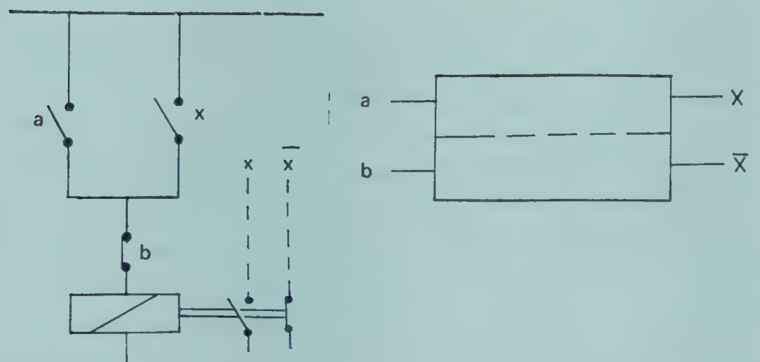


Fig. 7

storage cells in one device. Basically, the mode of operation of such static storage devices corresponds to that of the relay type storage. The storage is set by applying a signal in the form of a pulse to the set input 'a'. The set output 'X' becomes '1' and the clear output $\overline{X}$ 'O'. This condition is maintained indefinitely until the storage is once more cleared by applying a pulse signal to clear input 'b'. The set output X once again becomes 'O' and the clear output $\overline{X}$ assumes the state '1' which shows that the storage device is clear.

(b) Parallel to the indefinite-time storage devices, there are also what are known as definite-time storages. In conventional relay technology, this basic operation is performed by time delay relays. In SIMATIC this consists of a storage device in which automatic clearing takes place after a time delay set on an RC element, Figure 8.

If a pulse signal is applied to the input of such a timer, the latter produces a signal for a limited period T determined by the RC element. Its function is, therefore, similar to that of a time delay relay. A signal can be delayed by combining the timer with other basic functions.

The SIMATIC N System

SIMATIC N operates on the principle of binary signal processing whereby a transistor acting as a switch is operated in two states only, viz. "fully turned on" and "fully turned off". In the 'ON' state, the resistance of the transistor is very small, and assumes megohm values in the 'OFF' state so that a change in resistance of the order of about 5 to 6

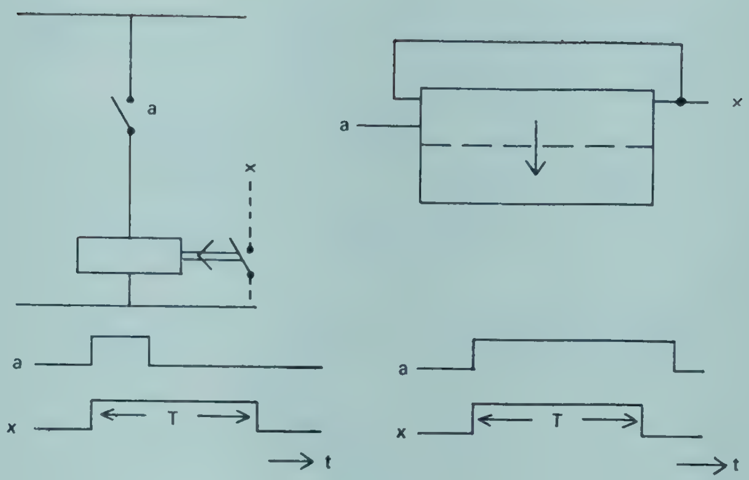


Fig. 8

powers of ten is achieved between the two states. In this respect, such a switching transistor can be compared to a contact which changes its resistance from the milliohm to the megohm level, i.e. by 9 to 10 powers of 10 between the closed and open conditions. The transistor in common emitter connection shown in Figure 9 is switched back and forth between the two states by applying or removing a base (control) current $I_s = 1$ which is fully adequate to drive the transistor into saturation.

In the 'OFF' or non-conducting state, the collector current I_c is practically zero (very low leakage current), and in the 'ON' or conducting state, the collector-emitter voltage UCE (residual voltage) is practically zero. From this, it follows that in both steady state transistor conditions, the power dissipation $P_D = I_C \times U_{CE}$ is very slight and assumes a greater value only during the switching time. If this switching time from the one state to the other is

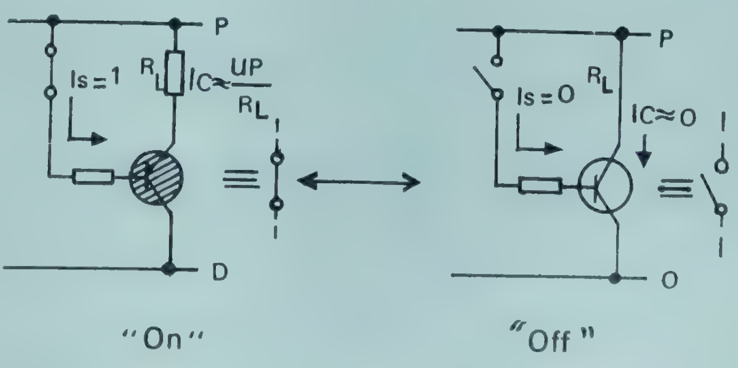


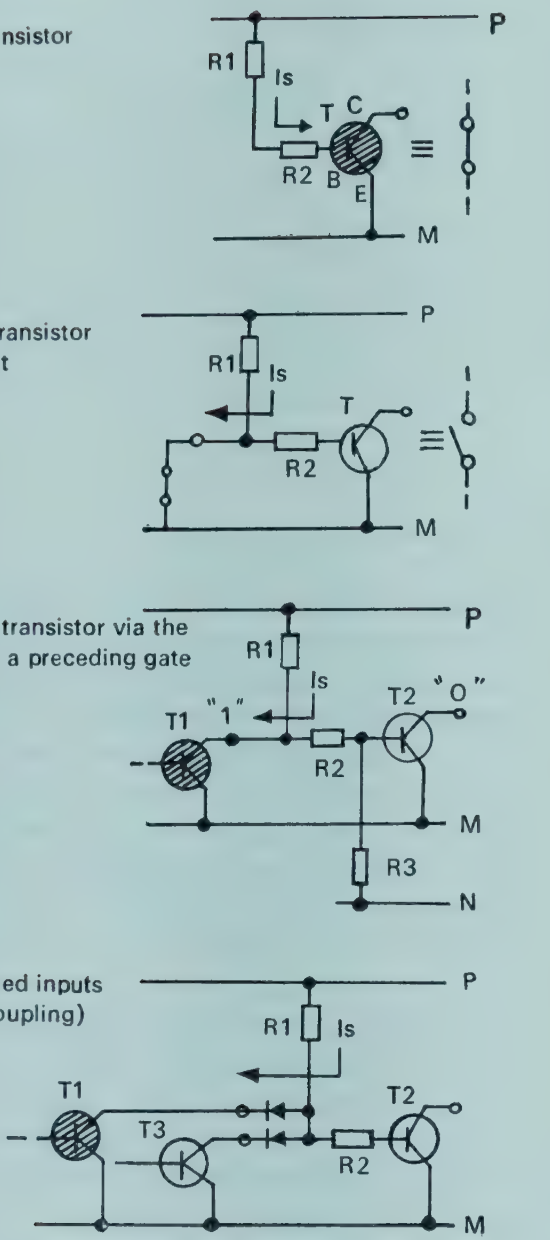
Fig. 9

a) Driving a transistor

b) Blocking a transistor via a contact

c) Blocking a transistor via the transistor of a preceding gate

d) Effect of ORed inputs (diode decoupling)



SIMATIC N Static switching. Mode of operation and signal language (Example NOR gate)

Potentials :
P : + 24 or + 12V
M : Reference potential OV
N : —24V or — 12V

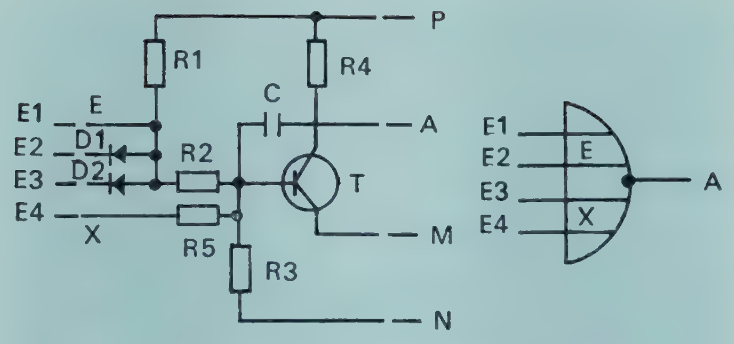
Fig. 10

very short, the heat losses of the transistor, being the time integral of the power dissipation, is negligible.

The circuits in Figure 10 illustrate the mode of operation of the NOR gate of the SIMATIC N system with switching transistors. Many binary signal processing functions can be performed by NOR gate combinations, so that this basic gate can be regarded as being representative of the fundamental characteristics of a static switching system. A further fundamental feature of the SIMATIC N static switching system is that the external base resistor (R_B in Figure 9) is sub-divided into two resistors R1 and R2. This voltage divider limits the base current I_S to a value which positively holds the transistor in the conducting state (a), via its collector-emitter circuit. Therefore, the transistor is thus the equivalent of a closed contact. If the centre tap of the input voltage divider is now connected to M potential, e.g. via a contact, the control current can be gated (b). The current now flows to M and the transistor is non-conducting. The transistor can also be blocked by the conducting transistor of a preceding gate or element (c). In this case R1 is the load resistor of the driving transistor. In order to ensure that the transistor is properly turned off even under adverse operating conditions (e.g. high ambient temperature) its base is also connected via a resistor R3 to the negative compensating voltage N (—12 or—24 V). In this operating state the transistor base, therefore, even assumes a slightly negative potential with respect to the emitter which is connected to M. This is governed by the division of the voltage N-M through resistors R2 and R3. However, since this effect serves mainly for temperature compensation, the negative compensating voltage can be ignored in the following explanations of the logic circuit functions.

Another important term for the understanding of static switching techniques is the signal language. By this is understood the representation of the two steady state conditions of the switching transistor by the signals 'O' and '1'. In the SIMATIC N system the '1' signal state is obtained when the transistor is turned on, the "O" signal when it is turned off. Since a conducting transistor connects the output to M potential via a low-ohm resistance, the '1' signal is used to denote this potential. The other potential P is thus denoted with 'O'. In Figure 10 transistor T1 applies "1" signal to the output of the gate and by blocking transistor T2, gives rise to "O" signal at the output of the gate. A "1" signal at the input gives "O" output signal and vice versa. Every transistor connected in this way in the basic circuit arrangement causes inversion or negation of the input signal in accordance with the logical NOT operation.

The function of the circuit shown in Figure 10 can be expanded in various ways by connecting passive



Basic circuit and symbol of the NOR gate of SIMATIC N
Fig. 11

input elements. Several diodes, for instance, can be connected to OR the input so that the gate can be driven by any of the transistors of several preceding gates Figure 10, T1 or T3. The decoupling effect provided by the diodes at the inputs is 'loss-free' so that the driving transistors can operate fully independently of each other without any mutual interference. The result of this series configuration of OR and NOT operations is the well known NOR gate.

The basic circuit of the NOR element is shown in Figure 11. The capacitor between the collector and the base acts as a capacitive negative feedback and limits the switching frequency to 10 KHz. This results at the same time in a precisely defined signal rise time which is practically independent of the physical properties of the transistor. The additional resistor R4 ensures that the output assumes a potential when the transistor is turned off. In this way it is also possible to check the functioning of the gate or element even when the output is not loaded with inputs of the following gates. The relatively high-ohm resistor is not necessary for the actual functioning of the circuit.

As regards the signal language, the following rules apply.

External:	'1'	-	Contact closed - P Potential
	'0'	-	Contact open - M Potential
Internal:	'1'	-	Transistor turned on - M Potential
	'0'	-	Transistor turned off - P Potential

The SIMATIC N System has the following advantages.

(1) When the transistor is turned off, the full P potential always appears at the output and when turned on, approximately M potential. When switching over from the one state to the other therefore, the full voltage is effective as signal. This is highly advantageous in the case of gates with dynamic or pulse inputs (i.e. inputs which respond to a signal change).

(2) The current amplification of the transistors is utilised to an optimum degree.

State of Art of SIMATIC Technology

In the electronics jargon, the SIMATIC N belongs to the 2nd generation since it uses dicrete silicon transistors. In the latest series i.e. the third generation, the integrated circuit technique is employed. It may not be immediately obvious that it is next to impossible to conceive all the process states of a large plant before commissioning and as such, design a control system which caters to the need even under the worst case. This takes us into the realm of freely programmable SIMATIC control systems where the interlocking logic may be changed as desired during construction, start-up or even operation of the plant. However, an attempt should not be made to solve all control problems with the freely programmable technique in view of prohibitive software cost.

SCANNING ELECTRON MICROSCOPE
SOME ASPECTS OF THE INSTRUMENT AND ITS APPLICATIONS
—M. R. THATTE

Introduction

We derive information about matter—animate and inanimate in the first instance, mainly by looking at it. Sight is our dominant sense, and our sensory world is primarily a visual one. Magnifying glasses, microscopes and telescopes provide extensions of our visual sense, enabling us to see, or see more clearly, small or distant objects. The invention and gradual perfection of these instruments, permitting the exploration of regions of the world inaccessible to our unaided eyes, is a major and well-known theme in the history of science.

There are three different types of microscopes in common use :

(1) Optical, (2) Conventional Transmission Electron Microscope (CTEM), and (3) Scanning Electron Microscope (SEM).

Figure 1 shows Siemens AUTOSCAN, a high performance, high resolution, fully automatic Scanning Electron Microscope. The salient properties of these three types of microscopes are given in Table 1.

Optical microscopy has had a history of approximately 300 years. Conventional transmission electron microscopy has been developed only during the last 40 years and scanning electron microscopy over the last 15 years.

The optical microscope and the conventional transmission electron microscope (CTEM) have contributed to the solution of problems in biology, metallurgy and many other sciences extensively and intensively.

In research, the elucidation of problems and verification of proposed theories have been facilitated by observation at the microscopic level.

In industry the demand for new materials has created the need for new quality control procedures on the one hand and failure analysis on the other. Microscopy in general has helped both quality control and failure analysis.

Industrial laboratories have been using optical microscopes for years but the conventional transmission electron microscope has featured in industry only through the Research & Development (R & D) wings of the industrial laboratories.

The reasons for this limitation do not arise from a lack of possibilities of use but the following basic causes :

Fig. 1 Siemens AUTOSCAN

(1) High cost

(2) Requirement of special sample preparation. Large size test samples encountered in industry cannot be accommodated and studied in the specimen chamber of a CTEM. Very thin sections of the sample, a few Angstrom units thick ($1 AU = 10^{-8}$ cm $= 10^{-10}$m) supported on copper mesh grids of 2—3 mm. diameter only, can be introduced in the instrument and studied. This is because of the fact that the high velocity electrons which act as the basic sensor in the CTEM must penetrate through the material to be studied and then get photographically recorded on the other side. The permissible specimen thickness for 100 kV electrons is thereby limited to about one ten thousandth of a mm. Special sectioning machines called ultramicrotomes have to be used for getting such thin sections of biological samples. For metallic samples, electrochemical etching/polishing, or vacuum evaporation techniques have to be used.

(3) Surface topography of specimens cannot be studied directly. An indirect method of replicating the surface by a thin and transparent plastic film and then shadowing the replica film with a thin deposit of heavy metal vapour to enhance contrast, is the only available method for the study of surface details.

The Scanning Electron Microscope (SEM) has advantages over CTEM with respect to all the three aforesaid points.

(i) Its cost is low: About 2/3rd or less of that of a CTEM.

(ii) Conducting specimens as large as 100 mm. can be directly accommodated in the specimen chamber of the instrument for study without any sample treatment. For non-conducting samples a thin conducting layer has to be deposited on the surface to render it conducting. This treatment is necessary in case of non-conducting samples to avoid the charging up of the specimen by the electron beam.

(iii) Surface topography and a glimpse into the three dimensional layout of surface details is often the key to the understanding of many problems. The SEM has a decided edge over the CTEM in this respect.

However, the resolution with which the CTEM yields information on internal structure is extremely high—almost approaching atomic dimensions with the latest machines. This is one of the greatest advantages of the CTEM.

Even though the SEM does not give information on internal structure, an accessory called the transmitted electron detector is available which yields information on the internal structure. It is of course true that for using this accessory, thin sections of specimens are needed. However, when this accessory is not in use, the normal SEM work on large size specimens is possible.

The CTEM also has a scanning accessory available with it but large size specimens cannot be used. Thin sections of the sample on 2 to 3 mm. diameter grids is still a necessity.

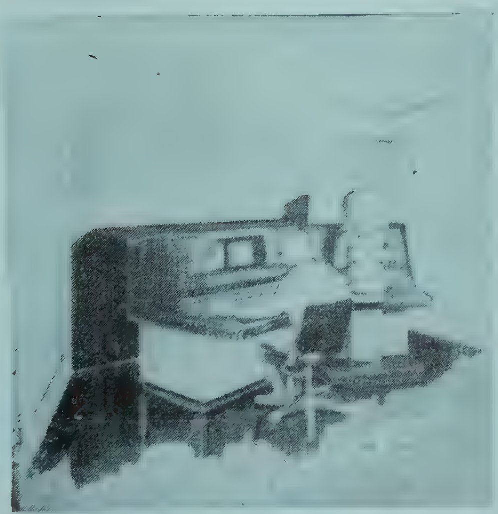
It is thus clear that here also the SEM is more versatile since it, in addition, continues to have the capability to accept large size samples.

For diffraction studies with the SEM an accessory is available—'the selected area electron channeling pattern system'. This accessory is of immense value in determining the perfection of single crystals, particularly in the semi-conductor industry.

From all the aforesaid discussions it is clear that the SEM will be more acceptable to industrial laboratories for elucidation and study of practical macro problems having microscopic origin. In research however, the CTEM and the SEM will complement each other.

An instrument incorporating the latest developments in both the techniques plus many more features has been announced by Siemens AG in October 1975—the Siemens ST 100F. Moreover in the conventional transmission microscopy field, two new introductions are: the CT 100F and the CT 150. The SEM as well as the CTEM will thus continue as techniques complementing and helping developments and applications of one to the other. Figure 2 shows the latest instruments from Siemens.

ELMISKOP ST 100F



ELMISKOP CT 150

ELMISKOP CT 100F

Fig. 2 The Latest additions in Siemens ELMISKOP family

Table 1

	Optical Microscope	Conventional Transmission Electron Microscope	Scanning Electron Microscope
Sensor	Light : Ultraviolet/visible	High velocity electrons : Accelerated by highly stabilised 20 kV to 150 kV or more	High velocity electrons : Accelerated by highly stabilised 1kV-50 kV
Aspect of the sensor used for signal development	Electromagnetic waves 3000-6000 AU	Wave nature of electrons : Typical 0.037 AU at 100 kV	Particle nature of electrons wave nature comes in play only for the transmitted electron detector accessory
Resolution limit	2000 AU	2 AU	Better than 100 AU in SE mode 50 AU in STEM mode
Possible magnification without further resolution of detail	1500-2000	1000000	240000
Depth of field at 1000x magnification	0.1×10^{-3} mm	10×10^{-3} mm Practically not achieved because of thin specimens	30×10^{-3} mm
Specimen preparation	Easy	Difficult	Easy
Capability in surface detail studies	Possible	Possible with replica technique	Very good
Capability in handling large samples up to 4 inches diameter	Possible	Not possible (only thin sliced samples)	Possible
Capability in internal structure studies	Possible	Very good	Possible with transmitted electron detector accessory
Capability in diffraction/ crystal studies	Very limited application	Very good	Very limited application (Selected area electron channeling studies with an accessory)
Elemental X-ray analysis (a) Wavelength dispersive (b) Energy dispersive	Not applicable Not applicable	Available Available	Available Available

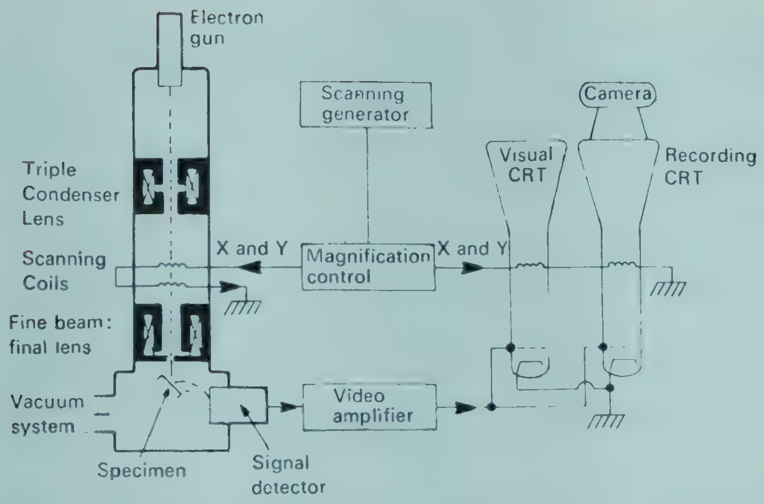


Fig. 3 Operational schematic of a Scanning Electron Microscope

Instrumentation

Image formation in a scanning microscope is very similar to television.

In television a distant scene is broken down into small picture points at the camera (Iconoscope) tube, when a fine electron beam scans it in a definite sequence. These picture points are fed into the transmitter and transmitted over electromagnetic waves and then reassembled at the receiver, in exactly the same sequence as transmitted from the camera tube. There must be a sufficient number of elements and they must be transmitted so fast that the eye can neither detect their presence nor the process of reassembly. The eye then continues to see the entire scene without seeing the tiny picture points of which it is built-up.

In a scanning microscope the sequence is basically the same as schematically represented in Figures, 3, 4, 5, 6 and the operational logic schematic Figure 7.

The specimen is scanned by a fine beam of electrons. Scanning is carried out in the same way as reading a page in a book. You start at the top, read all the words in the first line from left to right then return rapidly to the left to read the next line and so on until you arrive at the bottom of the page.

Both the visual and the camera tube of the SEM are blanked during the horizontal retrace period shown dashed in Figure 4 to make the retrace lines invisible. The retraces must be very rapid, of course, in order not to lose valuable picture information. As each horizontal line is scanned, the position of the beam must be progressively lowered so that the same line will not be repeated. This is accomplished by a vertical scanning motion of the beam from top to bottom, which is superimposed on the horizontal scanning motion. Moreover, after the scanning beam completes the last bottom line, it must be rapidly returned to the upper left hand corner as shown in Figure 5. This motion is called the vertical retrace to distinguish it from the horizontal retrace between each line. The vertical retrace is also blanked out. To obtain the maximum amount of picture detail called resolution or definition there should be as many horizontal lines as possible for each image.

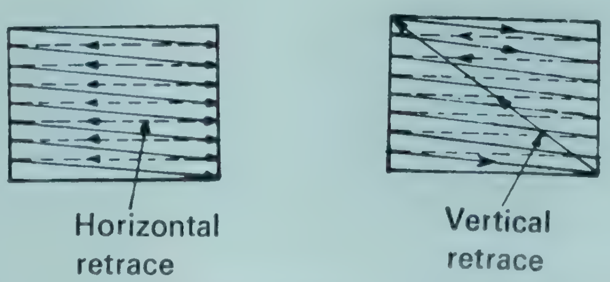
The scan generator of the AUTOSCAN has controls to change these parameters suitable to the need of a particular problem.

With reference to Figures 3, 6 and the operational logic Figure 7 the sequence in the building up of a SEM image is—

(1) Generation of the fine beam of electrons (beam diameter 40 to 80 AU) by the electron optical system, Figure 1.

(2) Interaction of the electron beam with the sample which produces secondary electrons/back scattered electrons. The distribution and energies of these electrons give the information signal Figure 6.

(3) Detection of the information signal in the form of electrons into a form in which it can be processed and utilised further. This is done by allowing the electrons to fall on scintillator. The crystal generates visible light flashes for each electron impinging on it. The flashes are conducted to a photomultiplier tube through light guides. The photomultiplier (PM) then gives the necessary electrical signal, Figure 6.



Figs. 4 and 5 Scanning the sample Easter (Television like) fashion

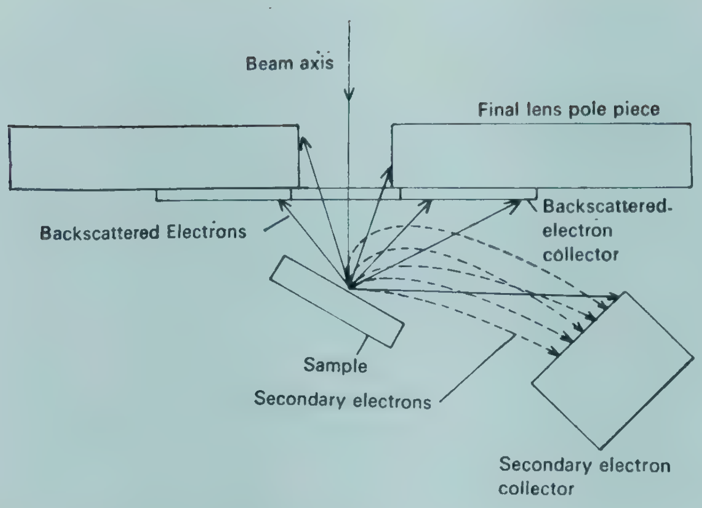


Fig. 6 Signal generation in a SEM

(4) The display—the electrical signal from the PM is then amplified and is used for intensity modulation of a cathode ray tube (CRT), Figure 1.

The adjustments to achieve the desired image are made on the visual CRT and the photographic record is finally obtained on the camera CRT. The AUTOSCAN uses a 2000 line high resolution CRT which enables imaging of greater areas than ordinary CRTs, without-sacrificing resolving power.

Conclusion

Development of the science of microscopy leading to three different types of microscopes—the optical, CTEM and the SEM has been discussed. Special advantages of the SEM in the solution of problems in industrial laboratories are mentioned. A brief reference to the latest instruments announced by Siemens AG shows the modern trends in the technique. A close similarity in image building between SEM and television is indicated. Operational anatomy of the SEM is reviewed.

(The next article will be devoted to concrete cases of actual applications of the SEM in various fields.)

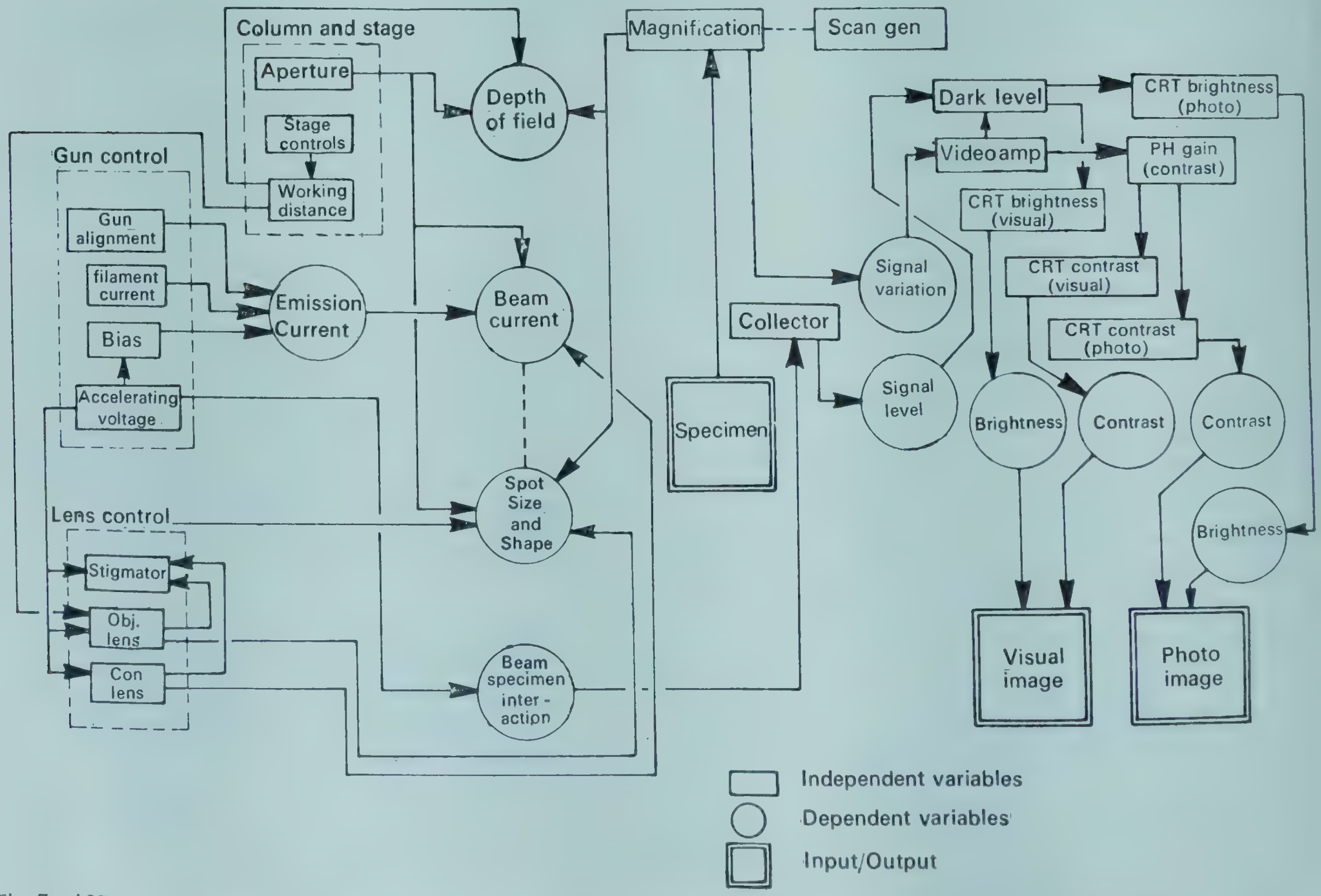


Fig. 7 AUTOSCAN operational logic

Piezoelectric Pushbutton
New Element for "pathless" switches

Elevators and television sets, in particular, have in many cases already been equipped with touch controls and proximity switches, where the user's finger brings about a change in the conductivity or capacitance of the sensor area and by doing so generates the actual switching signal. These sensor buttons are mechanically simple in design and very sound; what is more, they give the user a feeling of the "magic" of the technology he is using. However, sensors of this kind are sensitive to moisture and are therefore restricted to domestic use.

Following extensive research, Siemens is now able to present a new sensor element (B 39 910) based on the piezoelectric effect: A pressure-sensitive piezoceramic transducer responds to light pressure (approx. 150 g) by producing a voltage of about 0.8 V. The deformation that occurs is less than 0.5mm, so that the pushbutton can be described as a "pathless" switch. The actuating area can be designed as part of a virtually rigid and hermetically sealed surface. Moisture and soiling have no effect on the switching characteristics, and inadvertent touching does not result in false operation, since the switch has to be actuated with a definite minimum pressure. In view of these qualities, the piezoelectric pushbutton is predestined for equipment exposed to unfavourable environmental conditions as well as for consumer electronics, including portable equipment.

The pushbutton developed by Siemens is based on ferroelectric piezoceramics such as are already used for cigarette lighters and phono pickups. A thin foil, cast to form an edge-mounted transducer element whose top edge can be subjected to mechanical force and which is supported on either side to prevent bending, serves as a pressure transducer. The extremely slender shape of the transducer greatly increases the piezoelectric energy at a given pressure.

In order to protect the new element from false trigger action,

Fig. 2

which can be caused by vibrations of a particular amplitude and frequency, an RC lowpass filter is integrated in the pushbutton. 30% of the foil forms the protective top edge, while the other polarized part of the foil (approx. 65%) acts as the actual piezoelectric transducer. The whole is a solderable element that permits realization of virtually any case design. Pushbutton element B 39 910 is directly compatible with sensor ICs SAS 560 S/570 S and SAS 580/590, and together with additional adapter elements it is also compatible with the TTL, LSL and C-MOS families.

The piezoelectric pushbutton does not pick up quiescent current and is therefore suitable for battery-operated equipment such as portable radio and TV sets. A further advantage is its insensitivity to moisture, dust and other deposits, which, in conventional sensors, were liable to cause undesirable changes in

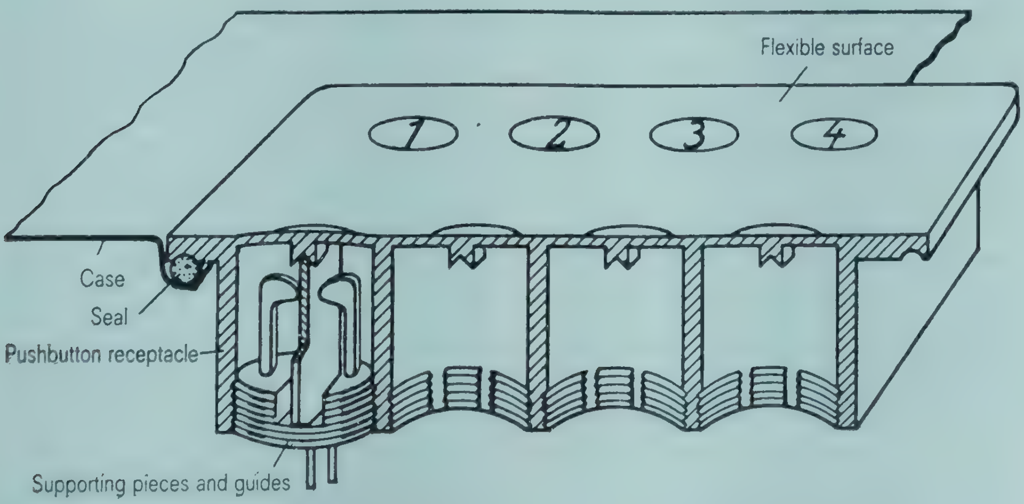


Fig. 1

the conductivity controlling the switching function. Consequently, it will now be possible to use pushbutton control panels on washing machines, kitchen ranges and other household appliances. The undiminished switching reliability of the "pathless" piezoelectric element in the presence of vibrations permits further applications in, say, electromedical equipment and process control systems. Yet another application is in pushbutton panels for telephones and computers.

Addition to the ESK Family

A large number of systems equipped with high-speed noble-metal contact (ESK) relays have been used for many years for telephone and telex switching centers throughout the world. Over 250 million ESK relays have been manufactured to date. Now the family of ESK telephone systems, which ranges from the small PABX right up to the international switching center, has been enlarged. The new member is the Siemens CP 24 Crosspoint System for public switching centers.

The development engineers who designed this new system were careful to choose the most suitable components. They continued using ESK relays in the speech path network, and used integrated P-MOS, C-MOS and TTL modules for the various control tasks. This technology made possible a system architecture which resulted in an extremely high degree of modularity as regards capacity, structure and operational features. This means that the telephone administrations each receive a system which is tailored to their individual requirements. The system design also increases subscriber convenience, since it permits the use of such features as data transmission, pushbutton dialing, uniform emergency numbers, barring of access to long-distance trunks, direct dialing into PABXs and identification of the origin of malicious calls.

The modular structure of the system means that the entire exchange cabling is of plug-in design as well as the functional units. This feature reduces the installation time and makes the system much easier to maintain.

The CP 24 Crosspoint System, which can be used in switching centers with anything from 100 to 6,000 line units, is already becoming an international success.

The South African Post Office recently decided to introduce it, and the first CP 24 switching centers have already been in operation for some time in the USA following an installation and test period of just under two months. The Company also has orders from Brazil.

Process-control Computer System Controls Cologne Underground Railway Junction

The world's first computer-controlled train guidance system for a rapid-transit network was recently placed in service in W. Germany for the Cologne Public Transport Dept. (KVB). The system, planned and supplied by Siemens AG, is built around two Type 320 process-control computers and controls all underground railway operations in the area covered by the Ebertsplatz interlocking, an area extending to seven stations. With its four radially converging lines, the Ebertsplatz underground station is a particularly important junction: up to 120 trains per hour have to pass through it. For a traffic volume of this magnitude, conventional means of automation such as relay storages would be too large and their performance unsatisfactory, especially as regards the necessary flexibility to handle unusual traffic situations.

Upon entering the area controlled by the interlocking, each underground train notifies the central process-control computer system of its number via an inductive trackside detector. From this number, the system detects the destination of the train and sets up its route accordingly. The computer takes into account certain factors, including the train length, since it is possible, for example, for two short trains to stop simultaneously at one platform. The system controls the route for turn-arounds—where the train enters a loop and is returned to its starting point—as well as the destination indicator boards on the platforms of the Ebertsplatz station fully automatically. On a large indicator panel in the interlocking control room the station inspector can follow all train movements and, if necessary, intervene manually, as in the case of diversions. Since the two computers generate the control commands simultaneously and independently of each other, each can immediately take over from the other in the event of its failure, without operations being affected in any way.

Flame Proof/Intrinsically Safe Electronic Signal Bells

To provide alarm, warning and indication whenever any hazard is anticipated in the underground Mines, a Flame Proof/Intrinsically safe Electronic Signal Bell has been developed by our associates, M/s. Bharat Bijlee Ltd. The construction of the Signal Bell is entirely of a different type and its functions deviate from the conventional type of Signal Bells so far used in the Mines.

Salient Features

The Signal Bell is basically a composite unit, comprising of input transformer as an integral part, along with signalling bells and associated electronic circuits. Hence, the complete equipment is compact and light. Moreover, the equipment is enclosed in a flame proof housing making it fully safe for operation under hazardous conditions.

Owing to the use of semi-conductor devices, the voltages and currents in the components are extremely low and hence intrinsically safe.

The semi-conductor devices increase the reliability of the circuit and provide a long span of life.

PVC or armoured paper cables can be used for connecting the Signal Bells, either through single entry or double entry arrangements.

The bell is primarily designed for 110V, 50Hz supply with short circuit current of 13mA. Bells for other voltages also can be designed on demand.

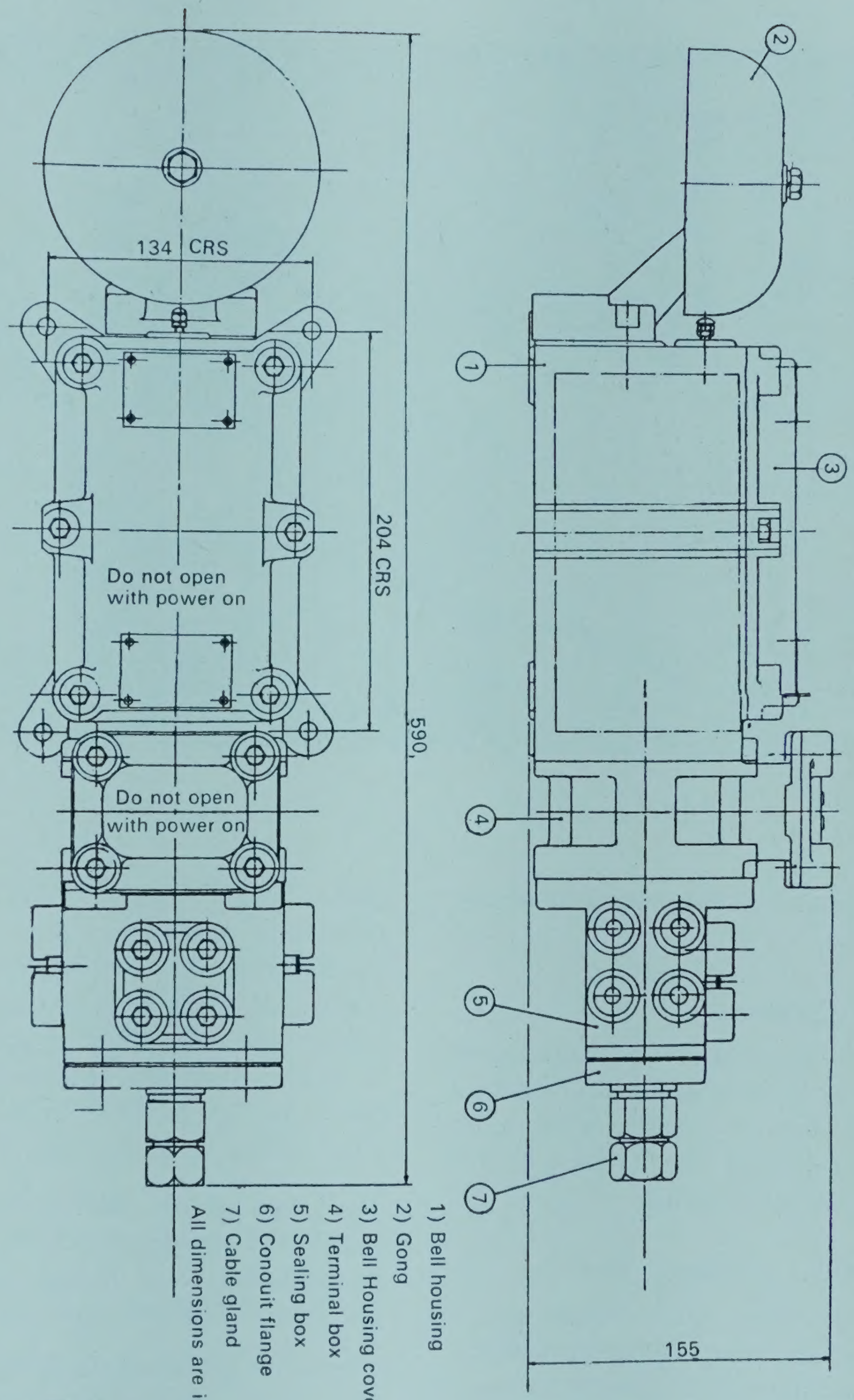


Fig 1.

Operation

The primary function of the electronic switch is to switch on mains power to energise the Signal Bell.

The transformer circuit is used merely to switch on electronic switch. The solennoid coil operating voltage is 110V. This voltage is switched to the coil by an electronic switch. Transformer step-down voltage (10V) is used to trigger the electronic switch, whenever the shorting terminals are shortened. The shorting terminal vol-

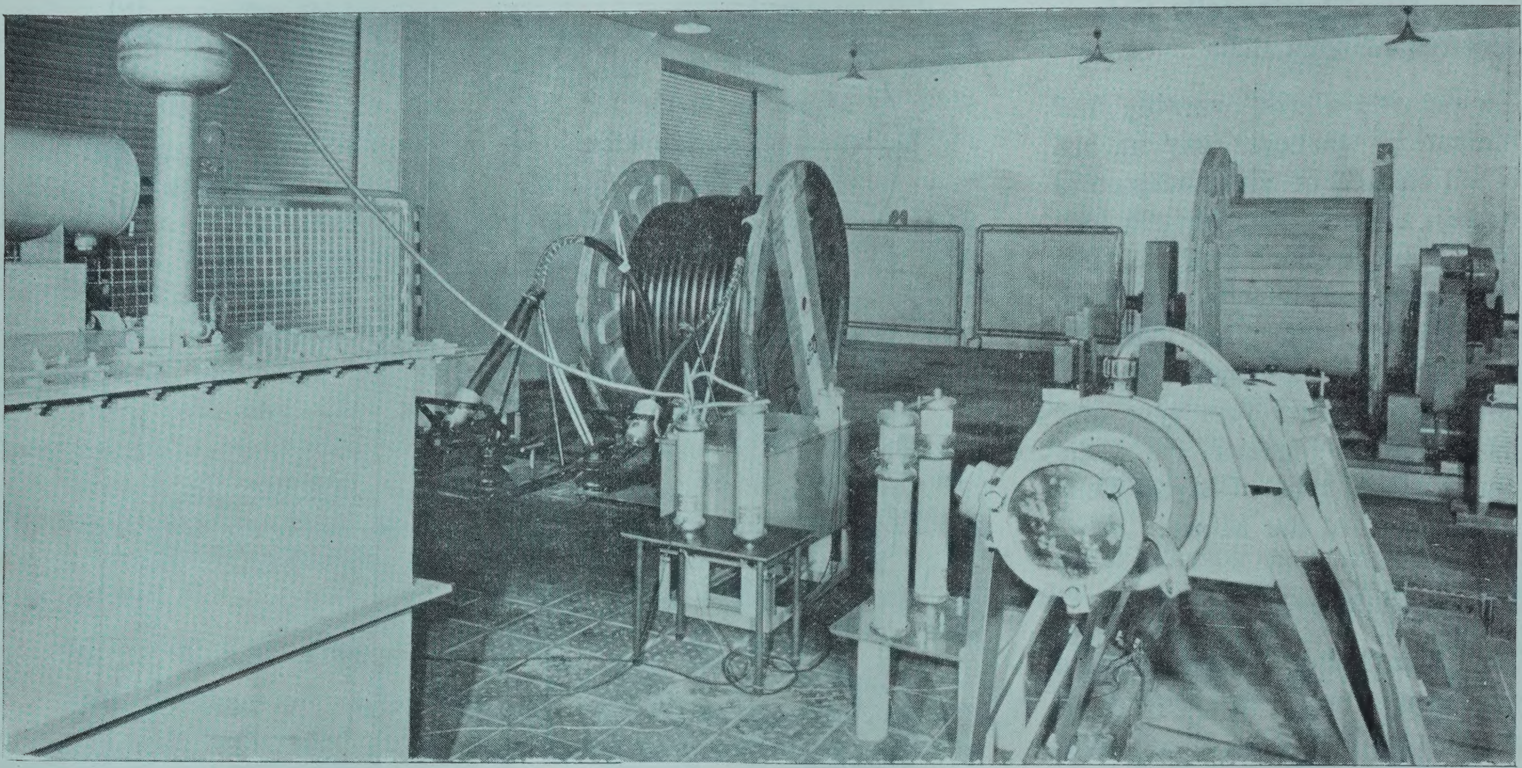


Fig. 2

tage and currents are intrinsically safe.

Certification

The Signal Bells have been tested and approved by CMRS Dhanbad and approved for use in Mines by DGMS and also covered by ISI Certification mark.

Partial Discharge Test

Discharges, either within insulation or from adjacent conductors, have been known to cause progressive deterioration and ultimate breakdown of the cable.

With the introduction of High Voltage Plastic Insulated Cables, where solid dielectric is applied by extrusion process, discharges have assumed prime importance. Hence, special methods for detection of discharges were developed. One such test "PARTIAL DISCHARGE TEST" is very significant in determining quality of High Voltage plastic cables. This test is incorporated in Indian Standard Specification No. 1554 (Part II) 1970, for 11 kV PVC cables as a Routine Test.

The photograph above shows the Partial Discharge Test Room at the factory, for testing of 11 kV grade TROPODUR cables.

The entire Test Complex is equipped with up-to-date Testing Equipment costing more than a million rupees. In order to detect even the smallest magnitude of partial discharges with highest sensitivity, it is essential that the complete test set-up is discharge-free. Accordingly, individual equipment such as High Voltage Transformer, Coupling condensers, etc. employed here are discharge-free. Even the L. T. supply is filtered through a special filter to suppress the mains-borne disturbances. Further, the complete Test Room is totally screened (Faraday-cage) to ensure that external electro-magnetic disturbances do not cause interference, in the observations. Also, specially designed elaborate cable terminations are used to ensure no discharges at the conductor termination. The entire lighting in the Test Room is with incandescent bulbs to avoid disturbance.

The right hand corner of the photograph shows de-ionised water filled pexi-glass tube used for scanning of the insulated cores. This is an additional quality control measure adopted in testing of TROPODUR High Voltage cables.

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